

# United States Trends in Lumbar Fusion Surgery for Degenerative Conditions

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**Study Design.** Retrospective cohort study using national sample administrative data.

**Objectives.** To determine if lumbar fusion rates increased in the 1990s and to compare lumbar fusion rates with those of other major musculoskeletal procedures.

**Summary of Background Data.** Previous studies found that lumbar fusion rates rose more rapidly during the 1980s than did other types of lumbar surgery.

**Methods.** We used the Healthcare Cost and Utilization Project Nationwide Inpatient Sample from 1988 through 2001 to examine trends. U.S. Census data were used for calculating age and sex-adjusted population-based rates. We excluded patients with vertebral fractures, cancer, or infection.

**Results.** In 2001, over 122,000 lumbar fusions were performed nationwide for degenerative conditions. This

represented a 220% increase from 1990 in fusions per 100,000. The increase accelerated after 1996, when fusion cages were approved. From 1996 to 2001, the number of lumbar fusions increased 113%, compared with 13 to 15% for hip replacement and knee arthroplasty. Rates of lumbar fusion rose most rapidly among patients aged 60 and above. The proportion of lumbar operations involving a fusion increased for all diagnoses.

**Conclusions.** Lumbar fusion rates rose even more rapidly in the 90s than in the 80s. The most rapid increases followed the approval of new surgical implants and were much greater than increases in other major orthopedic procedures. The most rapid increases in fusion rates were among adults aged 60 and above. These increases were not associated with reports of clarified indications or improved efficacy, suggesting a need for better data on the efficacy of various fusion techniques for various indications.

**Key words:** fusion, surgery rates, trends, surgical implants. **Spine 2005;30:1441–1445**

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Supported by Grant P60 AR 48093 from the National Institute for Arthritis, Musculoskeletal and Skin Diseases.

The statewide data organizations that participated in the HCUP NIS 2001: Arizona Department of Health Services; California Office of Statewide Health Planning & Development; Colorado Health & Hospital Association; Connecticut –Chime, Inc.; Florida Agency for Health Care Administration; Georgia –GHA, an association of Hospitals & Health Systems; Hawaii Health Information Corporation; Illinois Health Care Cost Containment Council; Iowa Hospital Association; Kansas Hospital Association; Kentucky Department for Public Health; Maine Health Data Organization; Maryland Health Services Cost Review Commission; Massachusetts Division of Health Care Finance and Policy; Michigan Health and Hospital Association; Minnesota Hospital Association; Missouri Hospital Industry Data Institute; Nebraska Hospital Association; New Jersey Department of Health & Senior Services; New York State Department of Health; North Carolina Department of Health and Human Services; Oregon Association of Hospitals & Health Systems; Pennsylvania Health Care Cost Containment Council; Rhode Island Department of Health; South Carolina State Budget & Control Board; Tennessee Hospital Association; Texas Health Care Information Council; Utah Department of Health; Vermont Association of Hospitals and Health Systems; Virginia Health Information; Washington State Department of Health; West Virginia Health Care Authority; and Wisconsin Department of Health & Family Services.

The conclusions and opinions presented here are those of the authors and not necessarily those of the National Institutes of Health or the Agency for Healthcare Research and Quality.

Acknowledgment date: November 17, 2004. Acceptance date: January 7, 2005.

The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

Federal funds were received in support of this work. 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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Studies from a decade ago demonstrated a rapidly increasing rate of lumbar spine surgery and important geographic variations in the use of spine surgery.<sup>1–4</sup> National survey data at that time suggested that rates of spinal surgery involving fusions were increasing more rapidly than the rates of nonfusion surgery. Those data also showed that surgical rates were increasing most rapidly among adults age 60 or over and for the diagnosis of spinal stenosis.<sup>1</sup> Since the completion of those studies, newer analyses suggest that, at least in the cervical spine, rates of spinal fusion have continued to rise and that a growing proportion of all operations involve a fusion.<sup>5,6</sup>

Since the earlier studies of lumbar surgery patterns, newer surgical implants have been introduced, and a variety of new technologies and surgical techniques have evolved. We therefore undertook an analysis to examine national trends in inpatient back surgery over the past decade to provide a more complete picture of practice patterns. Our study questions were as follows: (1) Did rates of lumbar spine fusion continue to rise during the 1990s? (2) Did rates increase more rapidly after introduction of intervertebral fusion cages in 1996? (3) Was any rise concentrated in certain age groups or diagnoses? (4) How did any increases in lumbar fusion rates compare with other major orthopedic procedures?

## ■ Materials and Methods

**Data Sources.** The Nationwide Inpatient Sample (NIS)<sup>7</sup> is a component of the Healthcare Cost and Utilization Project (HCUP) based at the federal Agency for Healthcare Research and Quality (AHRQ). Participating states submit administrative

data that individual hospitals provide on inpatient hospitalizations. Data include patient demographic information, International Classification of Diseases-9th-Clinical Modification (ICD-9-CM) diagnosis and procedure codes, and discharge disposition.

The NIS also routinely collects hospital charges. These include charges to all payers, including Medicare, Medicaid, private insurance, and uninsured individuals. Professional fees are not included. Furthermore, charges have a variable relationship to actual costs and do not reflect reimbursements.

Not all states collect statewide hospitalization data, and not all of those who do collect data participate in the NIS. The number of participating states has increased over time, from just 8 in 1988 to 33 in 2001. In 2001, NIS included data on over 7 million hospital stays from 986 hospitals in some 33 states representing all regions of the United States. The hospitals included in the 2001 sample accounted for about 85% of all hospitalizations in the U.S. Thus, the data have become progressively more representative of the national population. To obtain national estimates, sample weights are developed for each hospitalization, based on hospital and patient characteristics.

We used NIS data collected for 1988 through 2001. The data we used had no individual patient identifiers. The study activities were approved by the University of Washington Human Subjects Review Committee.

For studying hip replacement surgery and knee arthroplasty, we also used NIS data, as implemented in the interactive online Healthcare Cost and Utilization Project database of the AHRQ (HCUPnet), accessible at [www.ahrq.gov/HCUPnet](http://www.ahrq.gov/HCUPnet). Hip replacement and knee arthroplasty cases were identified using the Clinical Classification Software devised by AHRQ, which combines relevant ICD-9-CM procedure codes into clinically meaningful groups.<sup>8</sup>

**U.S. Census.** To calculate population-based rates of surgical procedures, we used yearly population estimates based on Census Bureau interpolations for intercensus years. All rates were standardized by the direct method, adjusting for age and sex, to the 2000 U.S. population. These analyses were performed with the SAS statistical program, version 8.2 for Linux.

**Selection of Cases.** Case selection was based on an algorithm using ICD-9-CM procedure codes, generally coupled with ICD-9-CM diagnosis codes. The basis for this algorithm has been previously described,<sup>9</sup> but the 1992 algorithm required modest updates. We selected only adults aged 20 and over.

Only diagnoses that are a source of low back pain or sciatica were considered. That is, the diagnosis had to pertain to the lumbar spine or sacrum rather than the cervical spine, thoracic spine, or an unspecified region of the back. These diagnoses included herniated discs; degenerative disc disease (ICD-9-CM codes for lumbosacral spondylosis, degeneration of lumbar disc, and unspecified lumbar disc disorder); spinal stenosis; possible instability (ICD-9-CM codes for disorders of sacrum including instability of the lumbosacral joint, spondylolisthesis, and spondylolysis); and nonspecific conditions such as lumbago, sciatica, sprain, and strain. Exclusions were patients with spinal fractures, pregnancy, vehicular accidents, and patients with nonmechanical low back disorders such as neoplasms, infections, and inflammatory diseases.

Surgical procedures were broadly characterized as laminectomy, discectomy, fusion, reopening of a laminectomy site, removal of an internal fixation device, or lysis of spinal cord and

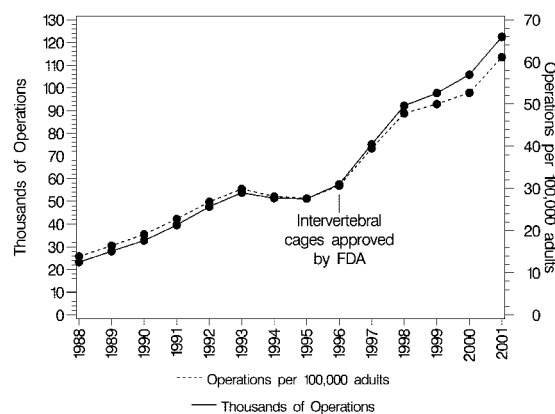


Figure 1. Lumbar fusion volumes and rates.

nerve root adhesions. For procedures that did not specify a location in the lumbar spine, cases were included if the diagnosis code specified a lumbar location (e.g., displacement of lumbar disc). The specific codes for exclusion and inclusion are provided in the Appendix (available for viewing on ArticlePlus only). Cases with any fusion procedure code (see Appendix Tables 5 and 6, available on ArticlePlus only) were coded as fusions regardless of what was listed as the principal procedure. Other admissions with multiple spine procedure codes were classified according to the principal procedure. Each admission was counted only once.

## ■ Results

In 2001, there were approximately 356,638 hospitalizations that met our criteria for “definitely lumbar” spinal surgery. Among these were some 122,316 lumbar spinal fusions for degenerative conditions, compared with 32,701 operations in 1990. These numbers of procedures correspond to age- and sex-adjusted rates of 61.1 operations per 100,000 adults in 2001, compared with just 19.1 operations per 100,000 in 1990. Thus, the rate of lumbar fusion surgery for degenerative conditions increased more than 2-fold from 1990 to 2001, a relative increase of 220% (increase of 42 operations per 100,000 divided by the rate in 1990). In contrast, lumbar fusions increased 100% during the 1980s,<sup>1</sup> so the pace of the increase in fusion surgery has accelerated. The slope of the increase became steeper in 1996, coincident with FDA approval of intervertebral fusion cages in the U.S. (Figure 1). In Figure 1, the slope of the rise after 1996 is significantly greater than the slope from 1988 through 1996 ( $P < 0.001$  for both number of operations and the adjusted rate per 100,000; this analysis performed with the R statistical program, [www.R-project.org](http://www.R-project.org)).

Because lumbar discectomy for herniated discs was increasingly performed on an ambulatory basis during the 1990s,<sup>10</sup> and because there is no current national database of ambulatory surgery, it is difficult to estimate whether the proportion of discectomies involving a fusion increased during this time. However, we could examine the proportion of other lumbar spine operations involving fusion, because most operations other than simple discectomy are still performed as inpatient proce-

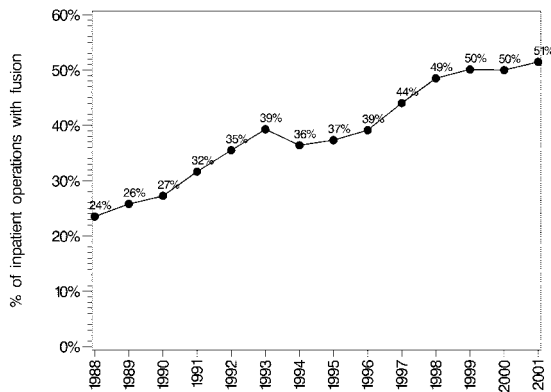


Figure 2. Percentage of cases involving lumbar fusion. For diagnoses of degenerative change, possible instability, or stenosis (excluding herniated disc).

dures.<sup>10</sup> For diagnoses of degenerative disc disease, possible instability, or stenosis, the percentage of cases involving a fusion increased steadily during the 1990s, from about 29% of inpatient operations in 1990 to 1991 to 51% of such operations in 2000 to 2001 (Figure 2). For individual diagnoses, these percents in 2001 were 93% for patients with a diagnosis of possible instability (spondylolysis or spondylolisthesis); 70% for patients with degenerative disc disease; and 26% for patients with a diagnosis of spinal stenosis.

As in the 1980s, the rates of lumbar fusion rose most rapidly in the oldest age group, over age 60 years. Between 1988 and 2001, rates of lumbar fusion surgery among this older group increased by 230%, compared with 180% among adults aged 40 to 59, and 120% among adults aged 20 to 39 (Figure 3).

Rates of lumbar fusion increased for all degenerative diagnoses. However, the greatest increase was observed for the diagnosis of degenerative disc. Fusion rates associated with herniated discs also rose steeply. Fusion rates for spondylolysis, spondylolisthesis, and stenosis also rose, but the increases were less striking, and the slope of increase was relatively steady. In contrast, the rise for degenerative disc or for herniated discs accelerated sharply in 1996, again coincident with the introduction of intervertebral cages (Figure 4).

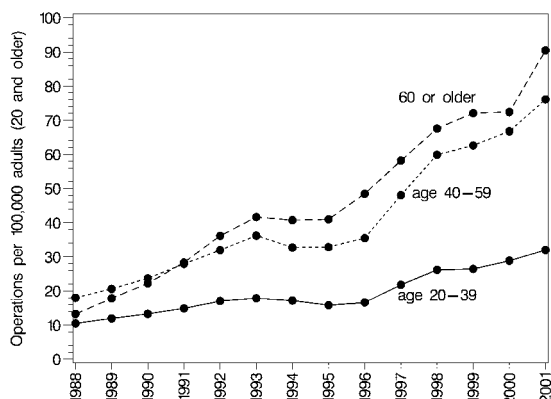


Figure 3. Rates of lumbar fusion by age category.

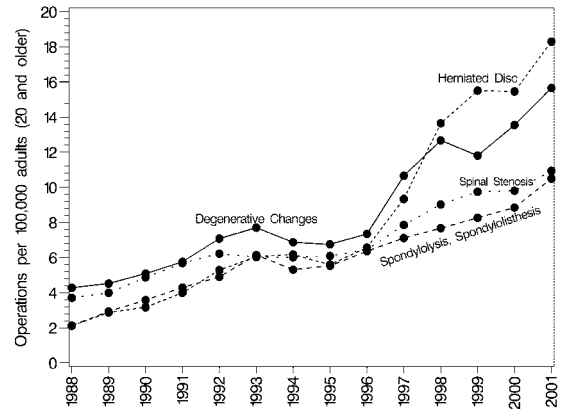


Figure 4. Lumbar fusion rates by primary diagnosis.

In comparing lumbar fusion with other musculoskeletal procedures, we focused on changes from 1996 to 2001. These were the most recent years we studied, and those with the sharpest increase in fusion rates. In 2001, there were almost three times more knee arthroplasties and hip replacements than lumbar fusions for degenerative disease. However, the knee and hip procedures increased by only 13 to 15% during the years 1996 to 2001, compared with 113% increase for lumbar fusions. Also, the median hospital bill for lumbar fusion was substantially greater than those for hip replacement or knee arthroplasty (Table 1).

## Discussion

Previous studies of lumbar surgery rates in the U.S. made use of the National Hospital Discharge Survey, Medicare claims, or state databases,<sup>1-4</sup> all of which differ in their sampling designs. However, the NIS is the largest multi-state sample of hospitalizations, and its estimates are similar to those derived from other sources. Despite some differences in methodology, comparison of the earlier results with our data indicate that rates of lumbar fusion for degenerative spinal conditions rose even more rapidly in the 1990s than in the 1980s. The proportion of all lumbar operations involving fusion also increased, so that by 2001, over 50% of all inpatient lumbar spine operations, other than those for herniated discs, included a fusion procedure. The most rapid increase began after 1996, coincident with the marketing of spinal fusion cages, a new type of spinal implants. The most rapid increase in fusion rates occurred among adults over age 60 and for degenerative disc disease other than herniated discs, stenosis, or spondylolisthesis.

Lumbar fusions for degenerative conditions increased at a several-fold faster pace than increases in other major orthopedic procedures, such as hip replacement and knee arthroplasty. Indeed, review of the HCUPnet data base indicates that lumbar fusion is among the most rapidly increasing of all major surgical procedures, and also one of the most expensive.

Although we cannot prove a causal association, the more rapid rise of fusion rates after the introduction of

**Table 1. Procedure Comparisons**

	Lumbar Fusions for Degenerative Conditions	Inpatient Hip Replacement	Inpatient Knee Arthroplasty
No. of procedures, 2001 (listed as primary procedure)	122,469	329,900	363,536
% increase in volume 1996–2001	113%	13%	15%
Mean hospital stay, days (2001)	4.5	5.4	4.5
Median hospital stay, days	4	4	4
Mean total hospital charges, 2001	\$39,906	\$28,234	\$25,309
Median total hospital charges	\$33,119	\$24,017	\$22,335
National Hospital Bill, 2001 (mean charges times no. of hospitalizations)	\$4.8 billion	\$9.3 billion	\$9.2 billion

fusion cages is striking. We are unaware of other major advances or major new studies concerning the efficacy of spinal fusion for degenerative discs that emerged in 1996 to otherwise explain this acceleration. The major clinical trial of Fritzell *et al*,<sup>11</sup> suggesting at least a short-term advantage of fusion over nonsurgical care for degenerative discs, was not published until December 2001. It seems at least plausible that the introduction and marketing of a new device led to an increase in the rates of fusion surgery without any real change in the indications for surgery.

Data on geographic variations in medical procedure rates suggest that back surgery rates are more variable than many other types of surgery and that spine fusion rates are more variable than spine surgery rates in general.<sup>12</sup> This finding is usually interpreted to suggest a poor professional consensus on the appropriate indications (and therefore rates) for performing spinal fusion.

Our data have some limitations. The use in this database of ICD-9-CM procedure codes, which did not indicate the use of surgical implants, made it impossible to determine what proportion of operations included surgical implants, much less to identify the type of implant. The rates of surgery we report probably underestimate true rates, because we excluded operations for which the location in the spine (cervical, thoracic, or lumbar) was ambiguous, though these were a small minority of all fusion cases (3%). Many patients have ambiguous or multiple diagnoses, so our classification into categories of herniated disc, spinal stenosis, degenerative change, or possible instability is crude at best. Because the NIS database has no patient identifiers, a single patient could be represented more than once if he or she had multiple operations.

In addition, these survey data are subject to sampling errors and recording errors. For example, changes over time in the hospitals sampled and the number of states involved might account for some of the variation in surgical rates. However, our comparison of NIS with other data bases (National Hospital Discharge Survey, Medicare claims) suggests highly concordant results for the trends shown here. Other comparisons suggest that these databases are highly concordant in general.<sup>13</sup> The NIS does not capture ambulatory surgery, so we cannot comment here on lumbar discectomy rates and the proportion that involve fusions. However, our analysis of the

short-lived National Survey of Ambulatory Surgery and several state ambulatory surgery databases indicates that spine fusion was rarely performed on an ambulatory basis during the study years.<sup>10</sup> Recording errors may occur when medical record data are not accurately transcribed into administrative databases. Nonetheless, our previous comparison of one statewide database with medical records suggested a high degree of concordance for diagnoses and invasive procedures.<sup>14</sup> Furthermore, the data in NIS are based on the data used for hospital billing, which have become more accurate over time and which are subject to audit.

Because fusion surgery is associated with more complications than discectomy or laminectomy alone,<sup>15,16</sup> it seems important to better define precise surgical indications for this approach. Furthermore, controversy persists over the efficacy of spinal fusion for several common degenerative indications.<sup>17</sup> The need to better define indications is especially clear for older adults, because the greatest rise in fusion rates is among the elderly, for whom complication rates are expected to be higher than in young adults. We hope that our study will stimulate future research in this area.

### ■ Key Points

- Lumbar fusion rates for degenerative conditions rose rapidly in the 1990s, exceeding increases in the 1980s. The proportion of all lumbar operations involving fusion also increased.
- Lumbar fusion rates accelerated after 1996, following approval of intervertebral fusion cages. The increase exceeded the rise in knee replacement surgery or knee arthroplasty.
- The most rapid increases in fusion rates were among adults aged 60 years and older and for diagnoses of degenerative change or herniated disc.
- The dramatic increase in fusion surgery rates suggests a need to better define the indications for fusion and the efficacy of fusion for various degenerative conditions.

### Acknowledgments

The authors thank Doctors Anne Elixhauser, Branko Kopjar, Judith Turner, and Chunliu Zhan for critical review and helpful comments on earlier drafts of the



manuscript. Bryan Comstock provided helpful statistical assistance and Kathryn Henne helped in preparation of the manuscript.

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## Point of View

John W. Frymoyer, MD

Over the past 15 years, Deyo and his colleagues at the University of Washington have refined the techniques to study large regional and national databases relevant to the treatment of low back disorders. Despite some methodological limitations (sampling and recording errors), these databases give a reasonably accurate picture of national trends in spinal surgery.

Deyo *et al* confirm that the annual rate for spinal fusion has been growing rapidly, particularly as that operation is used for the treatment of degenerative disc disease and for spinal stenosis in the population over 60 years of age. The growth trajectory accelerated even further following the Food and Drug Administration approval of fusion cages in 1996, far exceeding the annual growth rates for total hip and knee replacements.

One of the few benefits of aging is that you have lived through historical changes that may help inform current events. When I was a resident, surgery for hip arthritis was relatively rare because the risks of operation were significant and the benefits uncertain. Only young men with unilateral disease were eligible for hip fusion; cup arthroplasty required highly motivated, relatively thin patients; femoral prosthetic replacements often failed with time; and the results of osteotomy and “hanging hip” were unpredictable. The advent of total hip replacement (THR) was a revolutionary advance with predictable and excellent functional results obtained in patients with disabling arthritis of the hip. The annual rates for THR grew rapidly as more surgeons learned the techniques, as referring physicians became aware of the excellent results, and as patients with arthritis learned from the media and friends about the operation. THR went from an operation limited to a few centers, to an operation performed in all but the smallest hospitals. With that growth came enhanced awareness of the complications and longer term problems that caused failures, as well as a better appreciation the durability of total hip operation in properly selected patients. Today, the annual rates of THR and total knee replacement remain significantly variable as a function of geographic location, but the

relative risk for surgery appears to be fairly constant from year to year.<sup>1</sup>

Is it possible that we are seeing a similar evolution in surgery for lumbar spinal degeneration? Since the introduction in 1911 of spinal fusion techniques by Hibbs and Albee, there have been a variety of operations developed to treat degenerative spinal conditions. When a diagnosis of spinal stenosis is evident, the benefit of decompression versus decompression with fusion has been contested with few studies to scientifically inform that debate. When low back pain has been the predominant complaint, spinal fusion has been advocated. Initially, surgeons have been enthusiastic about new fusion techniques (facet, intertransverse process, anterior interbody, posterior interbody, and circumferential {360 degree} fusion techniques) only to discover the longer term results often were unpredictable and disappointing.<sup>1</sup>

New internal fixation devices also have been touted as the latest breakthrough in the management of low back disorders. Some of these devices, most notably the pedicle screw, may have enhanced the rate of biologic fusion but not necessarily the clinical results. Moreover, these devices have also been associated with increased morbidity, blood loss, and the risk of further surgery particularly in older patients.<sup>2</sup>

The introduction of the cage had been hailed as the latest advance in spinal surgery.<sup>3</sup> Deyo *et al* infer but cannot prove a causal relationship between the introduction of the cage in 1996 and the ensuing rapid increase in the annual rate of lumbar spine surgery. It would be fortuitous if the results of this new technique are so good that we are now observing a phenomenon similar to rapidly growing surgical rates that followed the introduction of total hip replacement? Alas, that seems unlikely.

Patients with degenerative hip disease usually present with a typical history and characteristic physical findings. Radiographs of the hip confirm the clinical diagnosis and only rarely are further studies required. In contrast many patients with degenerative spinal conditions have a history of nonspecific back pain and nonspecific physical findings. Even when there is a classic history of stenosis (claudication, forward flexed posture), the physical examination is limited in its ability to localize the level(s) of possible involvement.<sup>4</sup> Confirmation of a specific, localized clinical diagnosis by plane radiography is difficult with the exception of degenerative spondylolisthesis. As Kellgren and Lawrence<sup>5</sup> observed, most patients over age 60 have radiologic evidence of lumbar

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The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. 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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spinal degeneration as manifested in disc space narrowing, osteophytes, Schmorl's nodes, and endplate sclerosis. Population based computed tomography and magnetic resonance imaging studies demonstrate the prevalence of spinal stenosis is >60%, and disc degeneration is universal in people over age 60 without symptoms.<sup>4</sup> All of these factors make localization of the possible causative pathology difficult, particularly when there is multilevel disease. With advanced disc degeneration (stage III, IV) other diagnostic tests such as discography have even less predictive value.

Because the results of spine surgery are directly related to the accuracy of diagnosis, all of these complexities reduce the likelihood of success. Moreover, surgical success, particularly in the working age population, is profoundly influenced by psychosocial factors such as litigation, workers compensation, and psychological profiles<sup>6</sup>. When these negatively predicting factors converge, the results of spinal fusion are poor.<sup>7</sup> In short, managing a patient with lumbar pain is a far different challenge than managing the majority of patients with osteoarthritis of the hip.

Can technology overcome these problems in the way THR influenced the outcomes of hip surgery? The cage appears to reduce, but not eliminate, some of the problems associated with lumbar interbody fusions and does eliminate the morbidity associated with harvesting bone grafts.<sup>3</sup> The new technology may have improved on the rate of biologic fusion, but it is a demanding technique with significant potential complications. Although it is possible the cage has made an incremental improvement in results, it is unlikely that it is a technologic advance in a league with total joint replacement.

It seems likely that there are other factors significantly driving the increase in surgery. Part of the increase may be explained by an increase in the prevalence of symptomatic spinal degeneration in the growing aging population. It is likely that there is an increased awareness of spinal stenosis by primary care physicians as well as an increased public awareness of low back disorders as a result of media attention and the huge amount of information available on the Web. All of these events lead to increased referrals. However, the fact that there are more patients being referred still requires one more step to increase surgical rates; the surgeon must be prepared to recommend and perform the surgery. That leads to a possible conclusion that the supply of surgeons are a major drive in the growing rate of lumbar spinal fusion,<sup>8</sup>

although some data suggest the historic surgical rate in a given geographic area is a more powerful predictor.<sup>1</sup>

It has been shown that there are significant variations in lumbar disc surgery worldwide and in the United States. The single greatest predictor of the different rates is the number of surgeons capable of performing disc excision rather than the epidemiology of that disorder or the surgical techniques employed.<sup>8</sup> In the last two decades, spine surgery fellowships have become common and widely sought after by orthopaedists and neurosurgeons. A large and growing cadre of qualified spinal surgeons has been produced. All but the smallest hospitals want a fellowship-trained spine surgeon, not surprising since lumbar spinal fusion produces more revenue than total joint replacements. In their analysis, Deyo *et al* point out limitations in their cost data, "Professional fees are not included. Furthermore charges have a variable relationship to actual costs and do not reflect reimbursement."

Based on 40 years of experience, I suspect we are performing too many lumbar fusions given the reality that even well-trained surgeons and new technology are likely to overcome the diagnostic dilemmas, the less than certain outcomes, and the risks of significant complications that spinal fusion entails particularly in the older aged population. But perhaps it is a moot point, because the next major "breakthrough" is already in progress.<sup>9</sup> The next study from Deyo *et al* will be the documentation of rapid growth in intervertebral disc replacement.

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## Prognosis or “Curabo Effect?”

### Physician Prediction and Patient Outcome of Surgery for Low Back Pain and Sciatica

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**Study Design.** Prospective study with patient and physician questionnaires, clinical records, and imaging.

**Objective.** To compare physician expectations of surgery for sciatica and patient outcome.

**Summary of Background Data.** Physician accuracy in identifying individual patient prognosis is important for therapeutic decisions.

**Methods.** A total of 197 consecutive patients with low back pain and/or sciatica who underwent low back surgery in the University Hospital of Lausanne, Switzerland.

**Results.** Physicians predicted “a great improvement” of quality of life after surgery for 79% and “moderate improvement” for 20% (1% others); 39% of patients had no “minimal clinically important difference” in back pain after surgery, despite physician prediction of “great improvement.” Correlations between physician expectation and various dimensions of patient outcome were not significant, and agreement with patient global judgment of 1-year outcome was poor ( $\kappa = 0.03$ ). However, in a subgroup where the indication for treatment was not considered appropriate, physician prediction of “great improvement” was followed by greater improvement outcome on SF-36 mental component score ( $P = 0.05$ ), mental health (0.02), and general health (0.03) compared with patients where the physician did not predict “great improvement.”

**Conclusion.** Despite clear average improvement, surgeons tended to give overly optimistic predictions that were not correlated with patient outcome. For patients receiving a treatment not meeting explicit criteria of appropriateness, more optimistic physician expectation was associated with better improvement of psychological dimensions. Besides prognostic ability, the influence of physician expectation on patient outcome is discussed and the concept of “curabo effect” (differentiated from “placebo effect”) proposed.

**Key words:** back pain, sciatica, back surgery, discectomy, prediction, expectation, prognosis, treatment out-

come, recovery of function, disability, mental health.  
**Spine 2005;30:1448–1452**

Thirty years ago, surgeon prognosis was found to be a good predictor of outcome, better than statistical prognostic models.<sup>1</sup> More recently, however, surgeons were observed to give overly optimistic predictions for discectomy for sciatica<sup>2</sup>. Further studies of physicians' predictions are important because the ability to make a correct individual prognosis is an important component of clinical work. In particular, when several treatment alternatives exist, this ability makes it possible to present *personalized* anticipated risk/benefit ratios. Individual prognosis can be understood as a corrected general prognosis where the physician judges whether a particular patient is likely to obtain less or more than the theoretical outcome of a proposed treatment. A personalized prognosis may not be based solely on known mean outcome for similar patients in clinical studies, but rather it can also draw on personal experience and attention to each patient's unique set of physiologic and psychosocial characteristics. This process may resemble the use of a large database of patient files allowing for finer individual prognostic estimates than those derived from standard application of general clinical guidelines or randomized controlled studies<sup>3</sup> without reference to clinical experience.

In this study, we examined, within the context of surgically treated low back pain and sciatica, whether physicians were able to discriminate, within a group of similar patients in terms of disease and treatment, those who will have the best or the worse outcome.

## ■ Methods

**Study Population.** During 1 year all patients who were 1) referred for low back and/or radicular pain to the neurosurgical outpatient clinic of University hospital of Lausanne, Switzerland, 2) hospitalized in the same hospital and for whom a neurosurgical consultation was asked, or 3) referred to the emergency center for a neurosurgical consultation of low back pain and or sciatica were evaluated for inclusion into the study.

Included were patients who had low back pain and/or sciatica between 18 and 75 years of age with reasonable assurance of a possible 12-month follow-up. Patients with previous lumbar back surgery and prisoners were excluded, as were patients with other pathologies possibly interacting with the degenerative disc disease (*e.g.*, spinal stenosis, spondylolisthesis). Among 398 included patients (of which demographic and pathologic characteristics were presented elsewhere<sup>4</sup>), 197

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Acknowledgment date: May 26, 2004. Acceptance date: July 28, 2004. Supported by the Swiss National Science Foundation (Grant No. 3200-05925.97), the 450<sup>th</sup> Anniversary University of Lausanne Foundation, and Fond de performance (Projet No. 11, Etat de Vaud).

The manuscript submitted does not contain information about medical device(s)/drug(s).

Foundation funds were received in support of this work. 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.

The authors have no personal or institutional financial interest in materials described in their submission.

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were referred for back surgery. This study presents results of this group of surgically treated patients.

Written informed consent was obtained from patients before enrollment. After patient enrollment, the consulting surgeon determined the treatment plan based on a free clinical decision.

Patients were interviewed, and a neurologic assessment was performed before treatment and after 12 months.

**Clinical Data.** A detailed description of the methods of clinical data measurement is presented elsewhere.<sup>4</sup> For the purposes of this study, a detailed neurologic examination was performed and the following parameters were assessed: pain intensity, disability, health-related quality of life, functional and economic capacity, and neuroradiological disc pathology.

#### 1. Pain assessment

**Back pain and leg (radicular) pain were assessed by two instruments:**

##### A. Modified Roland Morris scale<sup>5,6</sup>

This widely accepted “Disability Questionnaire in low back pain” developed by Roland and Morris has been modified to include also leg pain in the wording of each question.<sup>7</sup> An individual patient’s score may vary from 0 (no disability) to 23 (severe disability).

##### B. Visual analog scale

On this scale, 0 represents “no pain” and 10 represents the most excruciating pain imaginable.

#### 2. Health-related quality of life

On the 36-item Short Form Health Survey (SF-36),<sup>7–9</sup> domains are scored from 0 (extremely poor) to 100 (optimal health). The question on patient self-reported health transition was used to compare global patient judgment on outcome with physician general expectations of improvement.

#### 3. Functional and economic capacity

With the Functional-Economic Outcome Rating Scale of Prolo *et al*,<sup>10</sup> the economic grade ranges from a low of 1 to a high of 10 (double scale: pain responses and effects on activities) and expresses the capacity for gainful employment or alternative comparable pursuits (housework, retirement activities).

#### 4. Neuroradiological assessment

Disc pathology was assessed (by the consulting neurosurgeons) according to the criteria proposed by Spengler *et al*<sup>11</sup> and Modic.<sup>12</sup> Disability scores correlated well with imaging findings, especially for leg pain scale, Roland-Morris, Prolo disability scales, and the SF-36 scores related to physical functioning, physical role, and bodily pain.<sup>4</sup>

#### 5. Physician expectations

The physician was asked before each surgical treatment, “how much the quality of this patient’s life would improve if she/he had lumbar surgery at this time?” The four possible answers were: “a great deal of improvement,” “moderate improvement,” “slight improvement,” and “no improvement at all.” “Quality of life” was not predefined in the physician’s questionnaire; therefore, several outcome measures related to quality of life were examined. The physician was also asked about the primary goal of his/her treatment, whether it was “alleviation of pain,” “improvement of neurologic functioning,” “prevention of future neurologic problems,” “improvement of physical functioning,” or “others.”

**Data on Treatment Appropriateness.** Following the standardized procedure of the RAND-UCLA appropriateness method,<sup>13–15</sup> explicit criteria were developed for surgical indications concerning low back pain and sciatica patients. Appropriateness was not communicated to either the consulting or operating neurosurgeon, who were thus blinded to the panel assessment of appropriateness of the indication for surgery.

A medical study coordinator was responsible for collecting the complete data of all included patients.

**Statistical Analysis.** All statistical analyses were performed using SPSS for Windows (version 10.0, SPSS) and Stata software, using *t* test for comparing continuous variables and  $\chi^2$  for categorical variables. Multiple regression models were used to adjust for potential confounders. The kappa statistic was used to evaluate agreement.

On the basis of previous studies, minimal clinically important differences were conservatively set at 3 of 24 points for the Roland-Morris disability questionnaire<sup>16</sup>, 10% for the SF-36 quality of life score,<sup>17</sup> 2 of 10 points for the VAS of back or leg pain,<sup>18</sup> and 3 points for the Prolo score.<sup>19</sup>

## ■ Results

Of the 197 patients enrolled into the study and surgically treated, 126 were male. Average age was 47.3 years (SD 13.8 years). The distribution of disc disease was as follows: 16 patients (8.1%) had no disc disease, 2 patients (1%) had a bulging disc, 4 patients (2%) had a disc protrusion, 151 patients (76.6%) presented with a disc extrusion, and the remaining 24 patients (12.2%) had a disc sequestration.

The L5–S1 disc was found to be pathologic in 43% of the patients, the L4–L5 disc in 33% of the patients, the L3–L4 disc in 13%, and the L2–L3 disc in 3% (8% none or unknown).

Operation was simple discectomy in 131 cases, discectomy + decompression in 56 cases, and discectomy followed by spondylodesis in 10 cases.

Physicians predicted “a great deal of improvement” of the patient’s quality of life after surgery for 156 (79%) of the 197 patients receiving surgical treatment (expected “great deal of improvement” for 86% in case of simple discectomy), “moderate improvement” for 38 (20%), and less than “moderate” for 3 (1%). This distribution did not significantly differ with sex, type of pathology, severity of disc disease, or appropriateness of surgery or the individual surgeon. There was, however, a significant difference, with a more frequently expected “great deal of improvement,” when the patient was younger (95% among those younger than 35 years, 70% among those older than 55 years, with regular trend in between;  $P = 0.03$ ), when the planned surgical technique was simple discectomy (86% *vs.* 67% for other surgical techniques;  $P = 0.002$ ), and when the main goal of the treatment was defined as “alleviate pain” (83% *vs.* 68% for other main treatment goals;  $P = 0.03$ ).

Patient outcome at 1 year was compared with physician expectations. When the surgeon predicted a “great deal of improvement,” 56% of patients said their health

**Table 1. Physician Prognosis and Patient Result: Global Judgment**

Patient Self-reported Outcome*	Physician's Expectation	
	Much Better (% column)	Better or Less (% column)
Much better	30 (19%)	5 (12%)
Better or less	126 (81%)	36 (89%)
Total:	156 (100%)	41 (100%)

Kappa = 0.03.

\*The question was: "compared to 1 year ago, how would you rate your health in general now?"

†"Less" means "slightly better or no improvement expected" and was only attributed to 3 patients.

status had not improved. This figure was slightly lower (46%) when physician expectation was lower. The agreement between physician expectations and patient judgment of outcome was poor (kappa = 0.03), with the latter appearing as globally less satisfied than physicians had expected (Table 1).

With various measured dimensions (including elements of SF-36, not shown), the difference was not statistically significant, except for minimal clinically important difference in leg pain (Table 2). A total of 39% of patients had no "minimal clinically important difference" in back pain, despite physician prediction of "great improvement."

There was also no statistical difference when analyzing separately those patients whose surgical intervention was considered appropriate or not, except for the SF-36 mental component score ( $P = 0.05$ ), mental health scale (0.02), and general health scale (0.03), when surgery was deemed inappropriate or equivocal (Figure 1). Analysis of proportions (%) with minimal clinically important

differences produces the same general picture, with again noticeable differences to be found in the group of inappropriate or equivocal surgery, where better improvement follows more optimistic physician's expectation, with statistical significance being reached on SF-36 scales of social functioning ( $P = 0.006$ ) and vitality ( $P = 0.04$ ), as well as on the Rolland-Morris disability score ( $P = 0.02$ ).

Finally, we studied whether the identified potential confounders (patient age, surgical technique, and the main goal of the treatment) could explain the observed differences in the subgroup of patients with treatment not meeting appropriateness criteria. In multiple linear regression, the differences found previously remained statistically significant. Multiple logistic regression was used to study whether differences found in "% with minimal clinically important differences" would also remain after adjusting for potential confounders. Differences in SF-36 social functioning and vitality scale remained statistically significant, while the Roland-Morris score difference tended to vanish ( $P = 0.059$ ).

## ■ Discussion

The objective of this study was to compare physician expectations of surgery for sciatica and patient outcome. The relation is not straightforward. On almost all patient dimensions of relevant indexes of health and health-related quality of life, the agreement is basically no different from chance alone. There is a tendency, however, for better improvement with higher physician expectation.

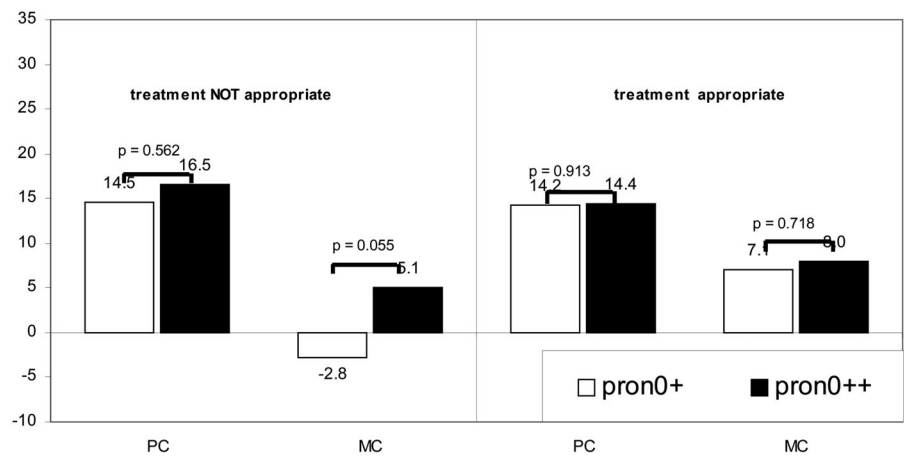
Our observation of 86% of predicted "great deal of improvement" in case of discectomy is strikingly close to the 87% found in another study.<sup>2</sup> They found mean differences for Roland-Morris score of 11.7 in the group of expected "great improvement" and 9.2 for the others. In

**Table 2. Physician Expectation and Outcome of Low Back Surgery: Baseline and Change in Mean Score at 1-Year Follow-up for Various Measures, With Respect to Physician Expectation (197 Patients With Low Back Pain and/or Sciatica, Surgically Treated)**

Score	Mean Score (SD) at Baseline			Change in Mean Score (SD) at 1-Year Follow-up			% of Patients With MCID		
	0/+ (physician expected moderate improvement [or less in 3 cases])		<i>P</i>	0/+ (physician expected moderate improvement [or less in 3 cases])		<i>P</i>	0/+ (physician expected moderate improvement [or less in 3 cases])		<i>P</i>
	++ (physician expected great improvement)			++ (physician expected great improvement)			++ (physician expected great improvement)		
Back pain VAS	6.3 (3.7)	6.1 (3.1)	0.824	-2.7 (3.4)	-2.8 (3.7)	0.921	63.4	60.9	0.858
Leg pain VAS	7.5 (2.9)	7.9 (2.3)	0.322	-5.0 (3.7)	-5.6 (3.5)	0.392	75.6	88.5	0.045
Roland-Morris	18.4 (4.5)	17.7 (4.1)	0.376	-8.3 (6.9)	-9.9 (6.7)	0.165	73.2	83.3	0.176
Prolo	2.8 (1.3)	3.4 (1.8)	0.032	3.7 (2.4)	3.8 (2.7)	0.859	75.6	67.3	0.348
Physical function (SF-36)	23.7 (22.6)	28.7 (24.4)	0.238	45.1 (26.9)	46.1 (31.3)	0.852	90.2	91.0	0.999
Bodily pain (SF-36)	12.8 (16.3)	15.6 (13.7)	0.259	37.8 (24.9)	41.6 (27.0)	0.412	97.6	91.7	0.308
General health (SF-36)	67.7 (19.7)	65.7 (18.9)	0.552	-6.0 (20.1)	-1.8 (19.8)	0.231	31.7	35.3	0.716
Mental health (SF-36)	51.7 (19.3)	51.6 (19.7)	0.979	10.3 (18.5)	16.0 (20.8)	0.117	68.3	67.9	0.999
Physical component (SF-36)	26.6 (7.0)	27.8 (7.1)	0.348	14.3 (9.2)	15.4 (12.1)	0.581	90.2	84.6	0.457
Mental component (SF-36)	41.8 (11.3)	41.1 (12.5)	0.776	3.7 (11.5)	6.7 (13.1)	0.193	51.2	55.8	0.603

MCID = minimal clinically important differences.

Figure 1. Change in SF36 physical (PC) and mental (MC) component scores according to physician prognosis (pron0+/pron0++) and appropriateness of indication.



our study, the figures are 9.9 and 8.3 for the whole group, the difference being perhaps attributable to the fact that patients in our group did not all undergo discectomy, as was the case for Lutz's group. In Lutz's study, only the difference in SF-36 physical function scores was different.

For selected dimensions of health-related quality of life, when the treatment is considered inappropriate or equivocal from an expert and criteria-based perspective, patients progress, in some dimensions of quality of life, appears better with more optimistic physician expectation. This was the case for those SF-36 dimensions with a strong psychological component and with the Roland-Morris disability score. Two types of explanations should be considered: Either the physician really predicts who has a better-than-average capacity of cure with a given treatment (prognosis ability) or physician optimism by itself acts in such a way that the patient does heal better. This hypothesis implies several possible mechanisms: the physician invests more time and energy in his/her work with this patient; the patient shows, for similar “objective” improvement, better ratings when the physician has expressed higher expectations. The phenomenon as a whole could be called a “curabo effect” (curabo = “I shall deliver a good cure,” in Latin). The term itself has apparently no record in the literature, but underlying mechanisms have been described as “self-fulfilling prophecies,” “quality of treatment alliance,”<sup>23</sup> and “influence (of therapist's optimism) on various elements of the actual treatment.”<sup>22</sup> The difference with placebo effect (found to be high in back pain<sup>20</sup>) lies in the fact that “curabo effect” is not attributed to the patient confidence but to the physician's belief in his/her own work. A rather similar phenomenon has been studied in psychiatry and psychotherapy. There the best single predictor of treatment outcome for depressed patients is the psychiatrist's optimism<sup>22</sup> and the strength of working alliance.<sup>21</sup> In our study, statistically significant differences in improvement were found in outcome measures with a strong social and psychological component. This may support the hypothesis that a “curabo effect” explains at least part of the observed correlations between physician predictions and patient outcome.

Prognosis ability or “curabo effect?” Be it self-fulfilling prophecy or predictions finer than those derived from a standardized model, the main point is that, in the case of “inappropriate or equivocal” back surgery, the physician may obtain, in some dimensions of health, what he/she expects, despite the lack of “objective” appropriateness of the chosen treatment.

Limitations of this study include the following: Since very broad categories were chosen for recording physician predictions, precise and more refined analysis of agreement was not possible. Most results are based on subjective data. It is possible that patients biased their outcome reports in order to fulfill their physician expectations. The manner in which agreement between physician expectation and patient global judgment was analyzed could conceal unexpected results because the questions were worded in a slightly different manner for patients (focus on “health status”) and physicians (focus on “quality of life”). The design of this study made it impossible to distinguish between a real predictive power of the physician and a possible causal effect of the expressed predictions, either on the quality of the delivered treatment or on the patient expectations. For this distinction to be made, the prognosis and the treatment should be performed by different physicians, and prognosis kept blinded to the patient and to the treating physician.

## Conclusion

This study showed that, despite clear average improvement, surgeons tended to give overly optimistic predictions, which were not correlated with patient outcome at 1-year follow-up. In one subgroup, however, where patients received a treatment not meeting explicit criteria of appropriateness, more optimistic physician expectation was associated with better improvement of psychosocial dimensions. Physician expectation may have by itself an influence on patient outcome.

## Acknowledgments

The authors thank Luca Regli, MD, Olivier Vernet, MD, Claudio Pollo, MD, Jocelyne Bloch, MD, and Mrs. Marie Ruiz for their support in recruiting patients.

### ■ Key Points

- In this follow-up study of surgery for sciatica, physician predictions were poorly correlated with patient outcome.
- When surgery did not meet official appropriateness criteria, more optimistic physician expectation was associated with better improvement of psychosocial dimensions.
- To explain these results, prognostic ability seems insufficient. An additional explanation is proposed and discussed: “curabo effect,” i.e., influence of physician expectation on patient outcome (symmetric to “placebo effect”).

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## Point of View

Sigurd Berven, MD and Jon D. Lurie, MD

The patient presenting with low back pain and sciatica may choose to pursue operative or nonoperative care. An informed decision requires accurate input from the surgeon or physician regarding the expected risk and benefit of each option. This study, along with prior research, demonstrates that physicians vastly overestimate the probability of success for surgery done for patients with low back pain with sciatica. Patient satisfaction with surgical management may be predicted by the relationship between patients' expected and their actual outcomes. The physician may have an important influence on patient expectations, and he or she faces a challenge in balancing the promotion of patient optimism and positive expectations against the introduction of accurate data and more realistic expectations.

The "curabo effect" postulates that the physician's expectations may influence outcome of patients; however, the conclusions that can be drawn from this study are severely limited. There is ample evidence in this study that physician expectations were unrelated to the degree of improvement in any of the important outcome measures. A small effect of borderline statistical significance was seen only in a post hoc subgroup of patients undergoing surgery for inappropriate or equivocal indications and was limited to domains of social and psychological components, excluding pain and functional outcomes. The weak trend toward physician expectations predicting these psychosocial outcomes is more likely to be attributable to chance or a "multiple comparisons effect"

than a "curabo effect." The authors provide no plausible explanation as to why physician expectations would only have an effect on patients getting "inappropriate" surgery. Perhaps more importantly, they did not assess or control for the patients' expectations.

Unmentioned in the manuscript are several interesting findings in the data. The physical component outcomes in the group receiving "inappropriate" surgery, as judged from their Figure 1, were no worse than those in the group receiving so-called "appropriate" surgery. This casts some doubt on the validity and/or utility of this categorization as done in the study. In addition, the lack of any baseline differences between the groups with higher and lower expectations suggests that the physicians did not incorporate potentially important factors such as the degree of physical impairment, mental health, and patients' general health perceptions into their subjective estimates of prognosis; it is therefore not surprising that no convincing relationship with outcomes was found.

Our inability to accurately predict outcomes may be a direct effect of our inability or unwillingness to accurately measure our own outcomes, and a common belief that established data are not generalizable or that the individual patient will beat the odds. The cost of such inaccuracy is that patients are misinformed about their options for care and make decisions and derive expectations based on poor data. Ultimately, the gap between physician expectations and observed outcomes serves to undermine the patient's ability to participate in informed decision-making. Improved outcome data from controlled trials of operative and nonoperative care for low back pain with sciatica are needed. Studies such as this one suggest that such data, presented objectively and in detail to patients, will be of far greater value in guiding patient decision-making than the most earnest and considerate of physician expectations.

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The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. 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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## The Role of Alternative Medical Providers for the Outpatient Treatment of Insured Patients With Back Pain

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**Study Design.** Analysis of health insurance claims from 2 large Washington State companies.

**Objective.** To evaluate the prevalence and cost of complementary and alternative medicine (CAM) provider use for back pain treatment.

**Summary of Background Data.** Washington State requires all commercial insurance to cover licensed CAM providers.

**Methods.** Outpatient claims for the treatment of back pain were analyzed by the International Classification of Disease-9 codes and provider type. The number of visits and expenditures associated with different forms of treatments were calculated.

**Results.** Back pain accounted for 15% of all outpatient visits, and these companies spent more than \$52 million on 652,593 claims submitted by 104,358 adults. Most people used only CAM (43%) or only conventional providers (45%) for back pain treatment, with merely 12% using both. Patients who saw only CAM providers had fewer comorbidities than the other 2 groups and made approximately twice as many visits as “conventional only” users (median 4 vs. 2). Average amount allowed per outpatient low back pain claim was lower for CAM visits (mean \$50, SD \$28) than for conventional visits (mean \$128, SD \$173). Total outpatient costs for the treatment of back pain were highest for the group using both CAM and conventional care (mean \$1079, SD \$1185), and lowest for the group using CAM only (mean \$342, SD \$429).

**Conclusion.** Many people with back pain use only CAM for their treatment. Although less expensive, this group also appears to be less severely ill. Because of the high prevalence of this condition, cost-effectiveness studies that include CAM therapies are still warranted.

**Key words:** back pain, alternative medicine, health insurance, health care use. *Spine* 2005;30:1454–1459

chiropractic in some form,<sup>1</sup> all 50 states license chiropractors, and approximately 85% of states license naturopaths, acupuncturists, or massage therapists.<sup>2</sup> The number of these providers is projected to double during the next decade,<sup>3</sup> growth attributed to consumer demand.<sup>4–8</sup>

In the United States, 70% to 85% of the population will have back pain at some time in their lives,<sup>9</sup> and back pain is one of the most common reasons for conventional physician office visits.<sup>10,11</sup> Analysis of alternative medical practices has shown that musculoskeletal complaints, in particular back pain, make up a substantial proportion of complementary and alternative medicine (CAM) practice.<sup>12</sup> Because many patients find conventional medical care for back pain of limited value, high levels of patient dissatisfaction have been reported.<sup>13</sup> In contrast, perhaps as a result of frequent provider-patient interactions, patient satisfaction with chiropractic is often high.<sup>14–17</sup>

Several recent studies and metaanalyses have looked at the effectiveness and cost of CAM treatments. These studies suggest that chiropractic may be equal in efficacy to conventional back pain treatments and that in some circumstances, massage may be the treatment of choice.<sup>9,13,15,18,19</sup>

The growing demand for CAM mentioned previously may have stimulated legislative efforts to mandate coverage of alternative providers by commercial health insurance. In Washington State, a 1996 law required all commercial health insurance to include coverage for every category of licensed provider that treated medical conditions usually covered by insurance.<sup>20</sup> Thus, acupuncturists, massage therapists, and naturopathic physicians were covered by most benefit packages by the year 2000. Another law that required self-referral for chiropractic was passed in 2000.<sup>21</sup>

The patterns of use and distribution of costs between conventional and alternative providers for the treatment of back pain have remained largely unstudied. We were able to use insurance claims data from 2 large commercial companies for the year 2002 to measure the use of CAM for the treatment of back pain. Our analyses addressed 2 questions: (1) What proportion of an insured population will use CAM *versus* conventional care in the management of low back pain if both are covered?; and (2) How are health care resources such as dollar expenditures and provider visits for the treatment of back pain distributed between CAM and conventional caregivers?

Alternative medical providers play a significant role in US medical care. Many insurance products now cover

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Acknowledgment date: April 15, 2004. First revision date: July 16, 2004. Acceptance date: July 19, 2004.

Supported by NIH R01-AT00891.

The manuscript submitted does not contain information about medical device(s)/drug(s).

Federal funds were received in support of this work. 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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## ■ Materials and Methods

**Study Population.** This analysis was limited to Washington State residents who were enrollees in 2 large health insurance plans directly regulated by the Every Category of Provider law in the year 2002. Excluded were publicly funded and self-insured plans that are exempt from state regulation under the Employee Retirement and Income Security Act. Because adults aged 65 and older use Medicare, the study sample was limited to adults 18–64 years of age who had both continuous enrollment in a single plan and complete claims information for the year 2002. Additional criteria used to select the population with back pain for this analysis included individuals: (1) who had at least one allowed outpatient visit with an International Classification of Disease (ICD-9) code<sup>22</sup> that was diagnostic for low back pain as defined for this study (Appendix 1, available for viewing on ArticlePlus only); (2) who had not been hospitalized or had undergone surgery for back pain; and (3) who had at least one visit to a defined conventional or CAM provider.

**Database Creation.** Two types of data files were received from the insurance companies. An enrollment data file, containing one record per enrollee, included a unique enrollee identification code, birth year, sex, residence zip code, and product type. Four insurance product types were identified:

1. Health Maintenance Organization: Organizations that use closed panels of providers, required referrals, utilization management, and other policies to control costs.
2. Preferred Provider Organization: Organizations in which the patient's share of costs is lower if the provider seen is within the organization's network.
3. Point of Service: It is like a Health Maintenance Organization but with the additional option of receiving care from outside providers, at a higher cost to the patient.
4. Traditional Indemnity (also called Fee For Service): It is a service in which patients can see any provider, and the provider submits claims to the insurance company based on those visits.

A claims data file, containing one record per claim, also contained the unique enrollee identification code, along with a claim number, service date, service location, ICD-9 codes, Current Procedural Terminology codes,<sup>23</sup> Healthcare Common Procedural Coding System codes,<sup>24</sup> line item charges (*i.e.*, billed, allowed, and paid), provider identification code, and provider type (including specific codes for acupuncture, naturopathic medicine, massage, and chiropractic practitioners). A visit was defined as an encounter with a provider having a unique date of service.

**Data Analyses.** Provider types were divided into 3 groups. CAM providers were defined as chiropractors, massage therapists, acupuncturists, and naturopathic physicians. Conventional providers were defined as physicians (including osteopaths and specialists), physical therapists, advanced registered nurse practitioners, and physician assistants. Providers who did not fit into either of these categories, including occupational therapists and psychologists, were put into a third category called "other." In some analyses, the naturopathic physicians, acupuncturists, and massage therapists are combined and referred to as "NAM" providers to address the categories of health providers that were usually not covered before 1997 but were covered in some form after.

The study population was divided into 3 mutually exclusive user groups: "CAM only," "conventional only," and "mixers." "CAM only" includes patients who had at least one visit for back pain to a CAM provider but no visits to conventional providers for that reason. "Conventional only" includes patients who had at least one visit for back pain to a conventional provider but no visits to a CAM provider for that reason. "Mixers" includes people who had visits to both CAM and conventional providers for back pain. People in these 3 groups may also have had visits to providers in the "other" category; however, people for whom all visits fell into the "other" category were excluded from the analyses.

We looked at comorbidities to see if patients selecting CAM care differed from those selecting conventional care. We created a count of comorbid conditions identified from diagnostic data from all visits during 2002 based on the major Extended Diagnostic Categories (EDC) developed at Johns Hopkins University.<sup>25</sup> We also defined a set of clinically significant back pain related diagnoses to see if patterns of care were different in this group than in the majority of patients with back pain whose diagnoses are less well-defined. These diagnoses were radiculitis (ICD-9724.4), myelopathy (722.7x), sciatica (724.3), spinal stenosis (724.0x), and disc displacement (722.0–2).

Several variables related to expenditures were available for each visit. The amount allowed by the insurance company was chosen as the closest proxy for expense because the billed amounts are highly variable and do not necessarily reflect the amount paid. In virtually all cases, the difference between the amount paid and the amount allowed was because of deductibles, co-payments, and coinsurance. Only visits that were allowed by the insurance company were included in the analysis (93.3% of all claims related to back pain). Thus, our data represent a minimum estimate for overall expenditures.

**Statistical Analyses.** Because of the large sample size for these analyses ( $n > 100,000$ ), very small differences are statistically significant. Therefore, only a few statistical tests were performed, and the clinical importance of observed differences will be emphasized in interpreting the results. Analysis of variance was used to compare the average number of visits between the provider groups, and the Medians test was used to compare the median number of visits between groups. Within each analysis of variance, *P* values for the comparisons among groups were corrected for multiple comparisons using the Bonferroni method.<sup>26</sup> Stata statistical software (version 8.0, StataCorp LP, College Station, TX) was used for all analyses. Multivariate logistic regression was used to identify factors associated with chiropractic or "NAM" use.

## ■ Results

### **Study Population and Claims History**

In 2002, 601,044 covered adults were eligible for inclusion in these analyses, and, of these, 497,597 (83%) had allowed outpatient claims for any reason. Back pain was diagnosed in 109,080 (22% of enrollees with allowed outpatient claims). Applying the back pain exclusion criteria previously described, 2240 individuals who made visits only to "other providers" and no visits to CAM or conventional providers were excluded, and 2482 individuals who were hospitalized or had undergone surgery for back pain were excluded, leaving a final study population of

**Table 1. Characteristics of the Study Population\***

	Covered Lives (%)	Enrollees With Allowed Outpatient Claims (%)	Back Pain Study Population (%)†
Total	601,044 (100)	497,597 (100)	104,358 (100)
No. of males	288,501 (48)	213,967 (43)	42,674 (41)
Median age (yrs)	43	43	45
County of residence			
No. in 400,000+	388,697 (65)	320,432 (64)	64,021 (61)
No. in 100,000–399,000	108,394 (18)	90,329 (18)	18,943 (18)
No. in <100,000	103,953 (17)	86,836 (17)	21,394 (20)
Western WA	443,590 (74)	365,831 (74)	74,338 (71)
Product Type			
No. in HMO	73,376 (12)	63,112 (13)	3556 (7)
No. in PPO	342,593 (57)	287,433 (58)	20,645 (42)
No. in POS	144,659 (24)	116,854 (23)	20,275 (41)
No. in traditional	40,264 (7)	30,186 (6)	5014 (10)
Insurance company			
No. in B	288,495 (48)	235,502 (47)	49,490 (47)
No. in C	312,549 (52)	262,095 (53)	54,868 (53)

\*Adults (age 18–64 years old) with private commercial insurance coverage in Washington State.

† Is comprised of enrollees who had at least one allowed outpatient visit with an ICD-9 code for back pain to a conventional or CAM provider, who did not have a hospitalization or did not undergo surgery related to back pain.

HMO = health maintenance organizations; POS = point of services; PPO = preferred provider organizations; WA = Washington.

104,358 individuals who made a total of 652,593 outpatient visits related to back pain during 2002. This total represents 15% of all outpatient visits for any reason.

Compared to all claimants, the back pain population was slightly older and significantly more likely to be enrolled in a point of service or traditional indemnity product (Table 1). Of the people with back pain, 41% were male, and 61% lived in counties with populations  $\geq 400,000$ . Median age was 45 for both males and females.

#### **Prevalence and Predictors of Provider Use**

Overall, 58,979 (57%) of the study population had at least one outpatient visit to a conventional provider for back pain, while 57,666 (55%) had at least one visit to a CAM provider. The 424,499 visits made to CAM providers accounted for 65% of all back pain visits (Table 2). Three quarters of these CAM visits were to chiropractors, accounting for 49% of all back pain visits; only 20% of back pain visits were to physicians. This propor-

tion is low because the median number of visits among people who saw at least one CAM provider was more than double than the median number of visits among people who saw at least one conventional provider (5 *vs.* 2), and the median number of visits to physicians was 1. Of those individuals seeing a CAM provider, 89% saw only one type of CAM provider.

Using a logistic regression model, we found that the type of CAM provider used differed by patient gender and county size, even after controlling for age, insurance company, type of insurance product, and insurance group size (data not shown). Males were more likely to use chiropractic care than females (odds ratio 1.11, 95% confidence interval 1.08, 1.14) but less likely to use naturopathic physicians, acupuncturists, or massage therapists than females (odds ratio 0.55, 95% confidence interval 0.53, 0.57). Chiropractic use was highest in the smaller counties. Sixty percent of study population mem-

**Table 2. Provider Types Visited and Number of Outpatient Visits for Back Pain by Those Using CAM or Conventional Providers**

	No. of People (%)	No. of Visits (%)	Median No. of Visits Among Those Using (25 <sup>th</sup> –75 <sup>th</sup> percentile)
Conventional	58,979 (57)	207,663 (32)	2 (1–4)
All MD	53,553 (51)	130,686 (20)	1 (1–3)
PT	11,130 (11)	71,858 (11)	5 (1–5)
Other (ARNP, PA)	3731 (3.6)	5119 (0.8)	1 (1–1)
CAM	57,666 (55)	424,499 (65)	5 (2–10)
Chiropractor	48,246 (46)	318,106 (49)	4 (2–9)
NAM*	14,979 (14)	106,393 (16)	5 (2–10)
Massage	11,694 (11)	84,936 (13)	5 (2–10)
Acupuncture	2701 (2.6)	15,500 (2.4)	4 (2–8)
Naturopathic physician	1609 (1.5)	5957 (0.9)	2 (1–4)
Other	11,126 (11)	20,431 (3)	
TOTAL	104,358	652,593	3 (1–8)

Note: People may appear in more than one category, so each category sums to more than the total.

\* NAM includes naturopathic physician, acupuncture, or massage (*i.e.*, all CAM other than chiropractic).

ARNP = advanced registered nurse practitioner; MD = doctor of medicine or osteopathy; PA = physician assistant; PT = physical therapist.



**Table 3. Number of People and Visits by User Groups\* for the Treatment of Low Back Pain in 2002**

	% of Males	Average Age (yrs)	No. of People With Back Pain Who Used (%):	No. (%) of All Visits for Back Pain by People Using:	Median (25 <sup>th</sup> –75 <sup>th</sup> percentile) Visits/Person†
"Conventional only"	42	44.2	46,692 (45)	170,129 (26)	2 (1–4)
MD only			29,998 (29)	59,855 (9.2)	
PT only			2327 (2.2)	12,802 (2.0)	
"CAM only"	41	42.8†	45,379 (43)	323,682 (50)	4 (2–10)
Chiropractor only			34,785 (33)	214,020 (33)	
NAM only			6254 (6.0)	42,155 (6.5)	
Massage only			4317 (4.1)	29,968 (4.6)	
Acupuncture only			962 (0.9)	5152 (0.8)	
ND only			617 (0.6)	2021 (0.3)	
"Mixers"	37	44.1	12,287 (12)	158,782 (24)	10 (5–17)
TOTAL	41	43.6	104,358	652,593	3 (1–8)

\*User groups: "CAM only," person saw at least one CAM provider and no conventional providers; "conventional only," person saw at least one conventional provider and no CAM providers; "mixer," person saw both CAM and conventional providers.

† "CAM only" group significantly younger than "conventional only" and "mixers" ( $P < 0.001$ ); "conventional only" and "mixers" not significantly different.

‡ All pair-wise comparisons significant at  $P < 0.001$ .

MD = doctor of medicine or osteopathy; NAM = naturopathic physician, acupuncture, or massage; ND = naturopathic doctor; PT = physical therapist.

bers living in counties with a population <100,000 had at least one chiropractic visit, compared to 50% among those in counties of 100,000–399,000, and 41% among those in counties  $\geq 400,000$ . Conversely, there was little difference in the use of "NAM" providers (15% in counties  $\geq 400,000$  vs. 14% in counties 100,000–399,000 and 12% in counties <100,000).

### Frequency of User Groups

For the 3 exclusive user groups: the "CAM only" group comprised 43% percent of the study population and accounted for 50% of the visits for back pain; the "conventional only" group comprised 45% of individuals and accounted for 26% of all visits for back pain; and the "mixers" comprised 12% of individuals and 24% of those visits (Table 3). Those individuals seeing only CAM providers were slightly younger on average than those seeing only conventional providers (42.8 vs. 44.2) but were equally likely to be male (41% vs. 42%).

The average number of back pain visits for those individuals seeing only CAM providers was significantly higher ( $P < 0.001$ ) than the average number of visits for those seeing only conventional providers, whether measured using mean (7.1 vs. 3.6) or median (4 vs. 2). However, the "mixers," who saw both CAM and conventional providers, had the largest average number of low back pain visits, with a mean of 12.9 (median = 10) ( $P < 0.001$  compared to both other groups).

The higher average number of visits in the "mixer" group is at least partly because of the fact that people in this group had to have at least 2 visits (one to a CAM provider and one to a conventional provider), while claimants in the "CAM only" and "conventional only" groups may have had only one visit. When the analysis was restricted to people who had at least 2 visits, the average numbers of visits were: "conventional only," 5.8; "CAM only," 8.5; and "mixers," 12.9 ( $P < 0.001$  for all comparisons). This result shows that the "mixer" group had a significantly higher number of visits than the

other groups, even among those people with at least 2 visits for back pain. Patients with one of the clinically significant diagnoses defined previously ( $n = 12,001$ ) were much more likely to see conventional providers only than the study population as a whole; 62% used conventional care only, and 19% used CAM care only.

There is some evidence that health status is associated with provider choice. "CAM only" users had claims for fewer categories of comorbidities, based on major EDC, than the other groups. "CAM only" users had an average of 4.2 major EDC recorded throughout the year compared to 4.9 for "conventional only" and 5.2 for "mixers" ( $P < 0.001$  for all comparisons). However, we do not know the extent to which differences in coding practices between CAM and conventional providers may have influenced the observed disparities.

### Outpatient Resource Use for Back Pain Visits

Average amount allowed per back pain visit to a conventional provider for a low back pain visit was \$128 (SD \$173), compared to \$50 (SD \$28) for CAM visits (Table 4). Variability in expense was highest for the "conventional only" group, reflecting the wide range of services among various types of specialists and primary care physicians in contrast to the more narrow scopes of practices of the CAM providers. As a group, the "CAM only" users included 43% of the people and 50% of the low back pain visits but only 30% of the total outpatient expenditures, while the "conventional only" group included 45% of the people and 26% of the visits but 45% of the total outpatient expenditures for the treatment of back pain. Although "CAM only" users averaged approximately twice as many visits per person as "conventional only" users, their mean total resource expenditure related to outpatient back pain care, per person, was significantly lower (\$342 vs. \$506,  $P < 0.001$ ), although median total resource expenditure was somewhat higher (\$211 vs. \$163,  $P = 0.004$ ) (Table 4). Much of the additional cost of conventional care is related to the use of

**Table 4. Average Visits and Dollar Amount Allowed per Person for Outpatient Visits Related to Low Back Pain and Visits for Other Reasons**

Visits	Annual Mean No. of Visits Per Person $\pm$ SD (median)		Annual Mean Dollars Allowed per Person $\pm$ SD (median) for:	
	Back Pain Related	Not Back Pain Related	Back Pain Related	Not Back Pain Related
"Conventional only"	3.6 $\pm$ 5.0 (2)	14.4 $\pm$ 15.8 (10)		
"CAM only"	7.1 $\pm$ 8.4 (4)	12.8 $\pm$ 14.1 (9)		
"Mixers"	12.9 $\pm$ 11.5 (10)	17.4 $\pm$ 17.9 (12)		
Average	6.3 $\pm$ 8.1 (3)	14.1 $\pm$ 15.4 (10)		
Allowed amounts	Annual Mean Allowed Cost per Visit for Back Pain $\pm$ SD (median)		Annual Mean Dollars Allowed per Person $\pm$ SD (median) for:	
	Back Pain	$\pm$ SD (median)	Back Pain Related	Not Back Pain Related
"Conventional only"	\$128 $\pm$ \$173	(88)	\$506 $\pm$ \$954 (163)	\$2211 $\pm$ \$4616 (974)
"CAM only"	\$50 $\pm$ \$28	(40)	\$342 $\pm$ \$429 (211)	\$1694 $\pm$ \$4038 (749)
"Mixers"	\$84 $\pm$ \$62	(68)	\$1079 $\pm$ \$1185 (664)	\$2410 $\pm$ \$4421 (1236)
Average	\$89 $\pm$ \$125	(60)	\$502 $\pm$ \$838 (219)	\$2010 $\pm$ \$4360 (890)

User groups: "CAM only," person saw at least one CAM provider and no conventional providers; "conventional only," person saw at least one conventional provider and no CAM providers; "mixer," person saw both CAM and conventional providers.

diagnostic imaging. When these claims were removed, average expenditures were \$320 for CAM care and \$382 for conventional care (medians \$185 and \$136, respectively).

Table 4 also displays the use of health care resources among user groups for outpatient visits related to back pain and outpatient visits for all other reasons. People who use only CAM providers for their back pain have fewer visits not related to back pain and lower annual dollar amounts, both for back pain visits and visits for other reasons.

## Discussion

We found that the prevalence of patients using CAM providers for the treatment of back pain is quite high when insurance covers CAM services. Also, the use of providers over a 12-month period by patients with back pain is highly segmented. Although chiropractic was the most common alternative service, 14% of patients visited acupuncturists, naturopathic physicians, or massage therapists. Thus, CAM providers, when covered by insurance, appear to provide an alternative to conventional medical treatment for many people with back pain.

The large financial burden on health care because of back pain is well known.<sup>11</sup> Our data confirm the high expense with 2 insurers in Washington State expending \$52 million on the study population in 2002 for outpatient visits alone. Our data also show the difficulty of comparing the expenditures among various user groups. Although costs are higher for conventional care, conventional providers appear to have sicker patients. The cost of conventional care may be positively skewed as a result of higher visit and procedure costs, or these patients may have more severe back problems. Alternatively, mean resource use per person is lower in the "CAM only" group. This result may reflect more efficient treatment of difficult patients or the absence of patients with complications and serious comorbidities that would inflate the mean.

It is also possible that some of the patterns we observed may have been related to differences in ICD-9 coding practices among various provider types. These differences could affect not only our assessment of overall comorbidity load but also whether individuals were defined with back pain and, thus, included in a particular user group.

We found that the "CAM only" group had lower overall resource use for the year 2002 than those who used conventional care for back pain. This is different from other studies of health care use, which have reported high health service use among CAM users.<sup>27-29</sup> These studies used visit data as their measure of use. We chose to evaluate both visits and expenditures, and found that they provide different information. Additionally, our large sample size allowed us to separate those individuals who used CAM providers only from those who used both CAM and conventional providers (the "mixers") for the treatment of low back pain. The "mixers" had much higher resource use than either the "CAM only" or "conventional only" group as well as indications of higher comorbidity load. If we had included the "CAM only" group with the "mixers" (*i.e.*, a group comprised of those who used any CAM for back pain), overall use by CAM users would have appeared to be equal to or more than the nonusers. Our data appear to delineate 2 different groups of people using CAM for back pain: those with heavier burdens of comorbidities who are heavy overall users of all health care; and those using CAM only, who tend to have fewer comorbidities and be lighter overall users of health care. We did not analyze the extent to which those who used CAM providers for back pain also used CAM providers for other types of outpatient visits.

We found the proportion of those individuals with back pain using chiropractors increased with decreasing county population. We speculate that this result occurred because of the important role chiropractors have

played in rural primary care for many years and the relative paucity of doctors of medicine in rural areas.

Our analysis of CAM use for the treatment of low back pain has several limitations. Distributions of visits and monetary use among people with back pain are highly skewed, with large outliers both in the total number of allowed visits (ranging up to 189), and the amount allowed per person (ranging up to \$55,000). Thus, the mean is not a good measure of the middle of the distribution. Because of this, medians are also presented. Although in a skewed distribution, mean does not give the best picture of the “typical” person in the group, it is more meaningful when discussing resource use for the entire group. In addition, the reported expenditures must be seen as minimum estimates because the only amounts considered were those for outpatient visits, which were submitted to the insurance company and for which a nonzero amount was allowed. There were undoubtedly additional CAM visits for which claims were either not submitted or not allowed because patients had surpassed allowed visit limits. Another important limitation in our analysis of resource use is that we did not include medications. These probably add significant amounts to overall resource use.<sup>11</sup>

Our study shows that certain types of research are still timely and essential. Musculoskeletal pain treatment trials should include measures of cost-effectiveness for the various approaches studied. Well-designed clinical evaluations of back pain treatment need to collect enough data to describe clearly the history and severity of illness, insurance status, care preference, and other features that may be needed to understand the outcomes from treatments of different types. Given the increasing expenditures for medical care and the rapid integration of CAM providers into insurance, studies measuring the value of CAM inclusion are badly needed.

### ■ Key Points

- The use of CAM providers for the treatment of back pain is common when these providers are covered by insurance
- Most patients choose either conventional or CAM providers exclusively for treatment of back pain.
- Treatment of back pain by CAM providers generally involves more visits but not higher overall cost than treatment by conventional providers.

Note: Appendix available for viewing online through ArticlePlus only.

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# Risk Factors for Infection After Spinal Surgery

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**Study Design.** A retrospective case control analysis of 48 cases of postoperative infection following spinal procedures.

**Objectives.** Spinal procedures that became infected after surgery were analyzed to identify the significance of preoperative and intraoperative risk factors. Characterization of the nature and timing of the infections was also performed.

**Summary of Background Data.** The rate of postoperative infection following spinal surgery varies widely depending on the nature of the procedure and the patient's diagnosis. Preoperative comorbidities and risk factors also influence the likelihood of infection.

**Methods.** A review of 1629 procedures performed on 1095 patients revealed that a postoperative infection developed in 48 patients (4.4%). Data regarding preoperative and intraoperative risk factors were gathered from patient charts for these and a randomly selected control group of 95 uninfected patients. For analysis, these patient groups were further divided into adult and pediatric subgroups, with an age cutoff of 18 years. Preoperative risk factors reviewed included smoking, diabetes, previous surgery, previous infection, steroid use, body mass index, and alcohol abuse. Intraoperative factors reviewed included staging of procedures, estimated blood loss, operating time, and use of allograft or instrumentation.

**Results.** The majority of infections occurred during the early postoperative period (less than 3 months). Age >60 years, smoking, diabetes, previous surgical infection, increased body mass index, and alcohol abuse were statistically significant preoperative risk factors. The most likely procedure to be complicated by an infection was a combined anterior/posterior spinal fusion performed in a staged manner under separate anesthesia. Infections were primarily monomicrobial, although 5 patients had more than 4 organisms identified. The most common organism cultured from the wounds was *Staphylococcus aureus*. All patients were treated with surgical irrigation and débridement, and appropriate antibiotics to treat the cultured organism.

**Conclusions.** Aggressive treatment of patients undergoing complex or prolonged spinal procedures is essential to prevent and treat infections. Understanding a patient's preoperative risk factors may help the physician to optimize a patient's preoperative condition. Additionally, awareness of critical intraoperative parameters will help

to optimize surgical treatment. It may be appropriate to increase the duration of prophylactic antibiotics or implement other measures to decrease the incidence of infection for high risk patients.

**Key words:** complications, risk factors, postoperative infection, spinal surgery. **Spine 2005;30:1460–1465**

Improvements in surgical techniques and instrumentation have allowed for enhanced patient outcomes for many difficult spinal conditions. However, many spinal procedures continue to require long operating times, extensive approaches, and implantation of significant amounts of instrumentation. These factors can contribute to postoperative complications, including surgical site infection.<sup>1–3</sup> Postoperative infections can have devastating sequelae, including failure of fixation, osteomyelitis, pseudarthrosis, and significant medical problems.<sup>1,4,5</sup> Furthermore, these infections are often difficult both to diagnose and treat.<sup>6</sup> One or more operative débridement combined with prolonged intravenous antibiotics may be necessary to treat and hopefully eradicate the infection. These treatments translate into increased hospital stays, recovery times, and cost for the patient and the health care system.<sup>1,7</sup>

Recognition of a patient's preoperative risk factors may allow for optimization and, in some instances, modification of his/her preoperative condition. Preoperative evaluation for risk factors may lead to alteration or adjustment of antibiotics or treatment of certain conditions. Given the scope and complexity of many spinal procedures, these interventions by the operating surgeon and the primary care physician have the potential to impact significantly a patient's overall outcome.

The purpose of this article is to examine a large number of spinal cases, including representative numbers of different diagnoses and procedures, to assess better the many factors that might increase the risk of infection. Because both simple and complex procedures are at risk for infection, analysis of a large and varied patient population allows for the examination of multiple variables and their role in postoperative infection. The preoperative and intraoperative risk factors examined expand on prior smaller reports that have analyzed the role of diabetes, smoking, previous infection, and the use of instrumentation and allograft.

## ■ Methods

A retrospective review of 1095 patients who underwent 1629 procedures at our institution from 1991 through 1997, inclusively, was performed to identify patients in whom a postoperative deep wound spinal infection developed. The 2 attending orthopedic surgeons on the Spinal Disorders Service performed

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Acknowledgment date: January 8, 2002. First revision date: March 3, 2003. Second revision date: September 7, 2004. Acceptance date: September 20, 2004.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. 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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all surgeries. Both pediatric and adult patients were included in the study. All types of diagnoses and procedures were incorporated into the analysis.

A total of 48 patients (4.4%) were identified from the patient charts and the operative log as having undergone a total of 100 postoperative incision and drainage procedures for their wound infections. Inclusion criteria as an infected case required surgical incision and drainage, and positive intraoperative deep cultures. A control group was selected using a random number generator and included the chronologically numbered case corresponding to those numbers during the period of study. Preoperative and intraoperative data regarding each patient were then collected using patient charts, computerized records, operative logs, and clinic notes. One patient was removed from the control group because he had had a postoperative infection and was included in the infected group. Patient characteristics recorded included age, gender, height, weight, and diagnosis. The preoperative patient risk factors reviewed included smoking, diabetes, body mass index (BMI), previous surgery, previous infection, steroid use, and alcohol abuse. The interval to development of the infection after the index surgery was also noted. Infections were categorized as early if they occurred less than 3 months after surgery.

Intraoperative factors that may have been considered possible risk factors for infection were collected and analyzed. This included type of procedure, operating time, estimated blood loss, and whether or not a combined procedure was performed in a staged manner. Additionally, the use of allograft and instrumentation was recorded.

Univariate and multivariate logistic regression was used to estimate and test the potential risk factors. This method produces the odds ratios that, for this rare outcome, estimate the multiplicative effect on risk of infection. Odds ratios  $>1$  indicate increased risk, while odds ratios  $<1$  indicate decreased risk. For univariate results,  $P$  values were compared to those obtained by the Fisher exact test and showed close correspondence in all cases.

All patients received preoperative antibiotics to cover commonly encountered organisms. A first generation cephalosporin was given unless the patient had a history of a significant allergy, in which case vancomycin was given. Antibiotics were redosed during prolonged cases ( $>6$  hours) or after significant blood loss. Antibiotics were continued for 48 hours after the procedure, except for simple decompressions, which only received antibiotics until they were discharged. Suction drains were left routinely in posterior spinal wounds where fusions were performed and removed 2–3 days after the procedure.

Indications for postoperative débridement included but were not limited to persistent wound drainage, fever, and pain. Patients with suspected postoperative infections were taken to the operating room for operative débridement. Débridement consisted of taking superficial cultures, thoroughly irrigating the superficial wound, then incising the deep fascia and taking separate deep tissue cultures. At least 9 L of pulse irrigation was used, necrotic tissue was removed, and instrumentation was scrubbed with dilute Dakin solution. The wound was then closed over suction drains. In several cases, repeat débridement was performed if the surgeon thought that it was indicated (*i.e.*, for delayed diagnosis, extensive necrotic tissue, or persistent signs of infection). Postoperative antibiotic treatment was tailored to the subsequent microbiologic analysis. Standard medical therapy following débridement included 6 weeks of intravenous antibiotics and, in some cases, long-term suppressive oral antibiotics if the surgeon and the infectious disease consultant thought this was indicated.

## ■ Results

The average age of patients in the infected group was older than that of the control group (47.8 *vs.* 40.0 years, respectively). Age  $>60$  years was a statistically significant risk factor for infection (odds ratio [OR] 2.9, 95% confidence interval [CI] 1.3–6.6,  $P = 0.011$ ). The infected group contained 17 patients older than 60 years (35.4%) as compared to the control group, in which only 15 (15.8%) of the patients fit in this category. There was a slightly higher proportion of females in both groups, but gender did not appear to be a strong risk factor (male OR 1.44, 95% CI 0.71–2.9,  $P = 0.37$ ). The majority of the infections occurred within 90 days of the initial surgery. The exact period was defined as the time from the procedure to diagnosis and treatment of the wound. The remaining 8 patients had their infections present clinically after the initial 3-month period. The onset of infection ranged from 5–840 days.

Analysis was performed comparing several preoperative risk factors for the infected and the control patients. All patients were initially analyzed as a group encompassing all patients. Because pediatric patients may differ, analyses were then repeated only on adults (18 years and older). Analyses restricted to pediatric patients were

**Table 1. Preoperative Risk Factors for All Patients**

Preoperative Risk Factor	No. of Infected Patients	No. of Control Patients	<i>P</i> Value	OR	95% CI
Sex (male)	23	37	0.37	1.44	0.71–2.9
Age ( $>60$ yrs)*	17	15	0.01	2.94	1.3–6.6
BMI $<22.3^*$	10	35	0.02	0.32	0.13–0.82
BMI 22.3–25.5*	12	34	0.04	0.40	0.16–0.98
BMI $>25.5$	22	25		Reference Category	
Smoking*	16	16	0.03	2.47	1.1–5.6
Previous surgery	26	45	0.48	1.31	0.64–2.7
Previous infection*	6	2	0.02	6.64	1.25–35.1
Steroid use	7	15	1.0	0.91	0.34–2.4
Diabetes*	5	0	0.004	Infinite	1.9–Infinite
Alcohol abuse*	4	1	0.04	8.55	0.91–81.5

\*Statistically significant.

**Table 2. Preoperative Risk Factors for Adult Patients**

Preoperative Risk Factor	No. of Infected Patients	No. of Control Patients	P Value	OR	95% CI
Sex (male)	21	29	0.25	1.58	0.73–3.4
Age (>60 ys)*	17	15	0.03	2.70	1.2–6.3
BMI <22.3	8	23	0.11	0.43	0.16–1.2
BMI 22.3–25.5	12	28	0.18	0.54	0.21–1.3
BMI >25.5	20	25		Reference Category	
Smoking*	16	16	0.06	2.26	0.98–5.3
Previous surgery	23	42	1.0	0.96	0.45–2.0
Previous infection*	6	2	0.02	6.08	1.13–32.6
Steroid use	7	15	0.81	0.80	0.29–2.2
Diabetes*	5	0	0.005	Infinite	1.7–Infinite
Alcohol abuse*	4	1	0.05	7.79	0.81–75.2

\*Statistically significant.

often not meaningful because of the small number of such patients (5 infected, 18 control), therefore, only a portion of these results are given. Statistical significance for increased postoperative infection in the entire patient population was established for diabetes, previous infection, smoking, and alcohol abuse. Factors that did not appear to be predictive of infection included previous surgery and steroid use. Table 1 provides a summary of the preoperative risk factors examined for all patients, while Table 2 presents data for adult patients only.

Patients with diabetes included those with both type I (non-insulin-dependent diabetes mellitus) and type II (insulin-dependent diabetes mellitus), and medical therapy varied accordingly. Five patients (10.4%) in the infected group were documented with diabetes, with 3 having type I diabetes and 2 having type II diabetes. None of the control patients had a history of diabetes ( $P = 0.004$ ). Examination of body habitus and the possible role of obesity was also performed. Calculation of BMI was performed for those patients whose height and weight were both available (infected 92% patients, control 99%). Lower BMI was statistically, significantly protective when all patients were considered (Table 1). Separate analysis of the adult patients showed a lower BMI still to

be protective, but slightly less so, and it no longer reached statistical significance.

A large proportion of both the infected and control patients had undergone previous spinal surgery performed at an outside institution (Tables 1 and 2). Cases in which the initial outside procedures had been complicated by postoperative infection had a higher risk of infection following procedures performed at our institution. A total of 12.5% of the patients who subsequently became infected had a history of previous infection compared with only 2.1% in the control group (OR 6.64, 95% CI 1.25–35.1,  $P = 0.02$ ).

As in previous studies, smoking was found to be a predictor for infection. A total of 33.3% of patients in the infected group smoked as compared to 16.8% in the control group ( $P = 0.03$ ). An arbitrary cutoff of 5 years was chosen for those patients who stated that they had stopped smoking. Low numbers from both groups had a documented history of alcohol abuse. However, we did find higher numbers in the infected group. A total of 8.3% (4 of 48) of the patients in whom infection developed had a history of alcohol abuse as opposed to 1.1% (1 of 95) of the control patients ( $P = 0.04$ ).

A wide variety of different diagnoses were treated in this study (Table 3). Only the diagnosis of neuromuscular scoliosis showed a trend toward increased risk (12.5% infected patients, 5.2% controls). Table 4 shows the distribution of the types of procedures performed. The most common type of procedure to become infected

**Table 3. Patient Diagnoses in the Infected and Control Groups**

Diagnosis	No. of Diagnoses in Infected Group (n = 48)	No. of Diagnoses in Control Group (n = 95)
Idiopathic scoliosis	16	37
Congenital scoliosis	0	5
Neuromuscular scoliosis	6	5
Spondylolisthesis	0	13
Spondylolysis	1	1
Spinal stenosis	10	8
Tumor/radiation	3	0
Rheumatoid arthritis	0	1
Trauma/infection	3	3
Herniated disc	4	9
Degenerated disc disease	0	6
Kyphosis	2	3
Flatback	0	2
Other	2	2

**Table 4. Types of Procedures in the Infected and Control Groups**

Type of Procedure	No. of Procedure in Infected Group (n = 48)	No. of Procedure in Control Group (n = 95)
Anterior spinal fusion	2	15
Posterior spinal fusion	15	39
Anterior/posterior spinal fusion	23	24
Decomposition/discectomy	7	9
Hardware removal	0	4
Anterior cervical discectomy and fusion	0	3
Other	1	1

**Table 5. Intraoperative Risk Factors for All Patients**

Intraoperative Risk Factor	No. of Factors in Infected Group	No. of Factors in Control Group	P Value	OR	95% CI
Staged procedure*	20	18	0.01	3.1	1.4–6.7
Allograft	20	35	0.59	1.22	0.60–2.5
Instrumentation	38	68	0.42	1.51	0.65–3.5
EBL (>2500cc)	24	41		Reference Category	
EBL (<1000–2500 cc)	9	29	0.17	0.53	0.21–1.3
EBL (1000 cc)	12	25	0.65	0.82	0.34–2.0
Time (>5 hs)*	36	52	0.03	2.5	1.1–5.4
Levels (≥14)	19	18		Reference Category	
Levels (7–13)*	7	22	0.03	0.30	0.10–0.89
Levels (1–6)	22	55	0.02	0.38	0.17–0.87

\*Statistically significant.  
EBL = estimated blood loss.

following surgery was the combined anterior/posterior fusion. A total of 47.9% (23 of 48) of the infected cases were combined procedures compared with 25.3% (24 of 95) in the control group.

Intraoperative risk factors are presented in Tables 5 and 6. Table 5 shows all patients, and Table 6 shows adult patients only. Staging of the anterior and posterior procedures also impacted the rate of infection. Staged procedures were performed with the patients under separate anesthesia, generally one week apart. Indications for staging the procedure included the patient's medical condition, complexity of the procedures, and expected duration of the procedure. Calculation of the odds ratio found that staged procedures had an approximate 3-times higher risk of infection than procedures performed with the patient under one anesthesia. A total of 41.7% of the infected group had undergone staged procedures compared with 18.9% of the control group ( $P = 0.005$ ). Patients who underwent staged procedures were routinely mobilized between stages if their spinal stability permitted and respiratory therapy was implemented as appropriate.

Blood loss and operating times were both higher in the infected group. However, stratification of these values revealed significance only for operating time. This significance was lost when the operating times were further

subdivided into adult patients only. A similar effect was found when the number of surgical levels was analyzed. The number of levels seemed to have statistical significance only when all patients were included in the analysis. Instrumentation and allograft were widely used, and no statistically significant difference was detected.

Results were also gathered to help define the nature of the postoperative infection. The most common infection involved *Staphylococcus aureus*, and the majority of the infections were monomicrobial. A total of 18 different types of organisms were isolated from the spinal wounds. Table 7 shows the frequency of the most common types of organisms cultured. A number of patient's wounds grew more than one organism. Table 8 shows the number of organisms cultured from each of the 48 patients.

## ■ Discussion

Spinal procedures have historically had higher rates of infection in comparison to other orthopedic procedures. The rates previously quoted in the literature vary widely (0.3% to 9%) depending on the type of procedure, patient population, and preoperative diagnosis.<sup>1,2,8–11</sup> This result compares to an infection rate of approximately 1% to 2% in the primary total joint arthroplasty literature, although the rate is higher with revision surgery.<sup>12</sup>

**Table 6. Intraoperative Risk Factors for Adult Patients**

Intraoperative Risk Factor	No. of Factors in Infected Group	No. of Factors in Control Group	P Value	OR	95% CI
Staged procedure	17	17	0.06	2.31	1.0–5.3
Allograft	17	32	0.85	0.92	0.42–2.0
Instrumentation	33	53	0.40	1.49	0.62–3.6
EBL (>2500 cc)	20	34		Reference Category	
EBL (1000–2500 cc)	8	22	0.34	0.62	0.23–1.7
EBL (<1000 cc)	12	21	0.95	0.97	0.39–2.4
Time (>5 hs)*	31	42	0.08	2.17	0.95–4.9
Levels (≥14)	15	15		Reference Category	
Levels (7–13)	6	12	0.27	0.50	0.14–1.7
Levels (1–6)	22	50	0.07	0.44	0.18–1.1

\*Statistically significant.  
EBL = estimated blood loss.

**Table 7. Types of Organisms Cultured From the Postoperative Infections**

Types of Organisms	No. of Patients
<i>S. aureus</i>	27
<i>Staphylococcus epidermidis</i>	18
<i>Streptococcus</i>	2
<i>Escherichia coli</i>	4
<i>Pseudomonas aeruginosa</i>	4
<i>Enterococcus</i>	11
<i>Candida</i>	1
<i>Enterobacter</i>	3

Our overall infection rate was 4.4%, which is in the mid range for the majority of large studies. Previous studies have shown that much of the variability in the incidence of postoperative spinal infection lies in the nature of the procedure. The rate of infection after simple discectomy is approximately 1%. This percentage increases to 2% to 5% in the case of a posterior spinal fusion. The addition of instrumentation to a posterior spinal fusion increases the rate up to 9%.<sup>1,9,11,13</sup> Overall, the rate is lower for anterior spinal fusions (<1%) and for cervical fusions (range 0.1% to 3%).<sup>13–15</sup> Procedural complexity was also a common denominator in our study. We found the most frequently infected procedure in our study to be a combined anterior/posterior fusion.

The focus of our study was to define further significant preoperative and intraoperative factors that contribute to an increased incidence of postoperative infection. While comparing our infected group with a randomly selected control group, we found significant differences among the incidence of several preoperative risk factors. The operating surgeon should have an understanding and awareness of his/her patient's preoperative risk factors. Some of these risk factors can be altered before surgery. Maximizing a patient's preoperative condition may help to prevent or limit complications.

Previously identified risk factors include malnutrition, diabetes, smoking, immunocompromised hosts, and obesity.<sup>9,15–19</sup> Klein *et al*<sup>18</sup> found that 25% of the patients in their study undergoing elective lumbar surgery were malnourished according to their criteria. This percentage was higher in the older patients. Furthermore, these investigators found that 11 of 13 wound complications occurred in malnourished patients. Although the retrospective nature of our study did not permit analysis of nutritional factors, we found that staged procedures, well accepted as higher nutritional risks, were at in-

creased risk for infection. Additionally, we found a statistically significant risk for those patients older than 60 years.

Smoking was a significant preoperative risk factor as was a documented history of alcohol abuse. We also found a significantly higher number of patients with diabetes and those with previous surgical infections in the infected group. Similarly, Simpson *et al*<sup>19</sup> found delayed healing and persistent draining affecting 24% of the patients with diabetes in their study. Infected patients also had increased BMI in comparison to control patients, but this factor was not statistically significant when pediatric patients were excluded. The role of obesity does vary from study to study, with several investigators reporting an increased risk.<sup>9,16,19</sup>

A higher percentage of patients with neuromuscular scoliosis was reported in the infected group. However, given the diversity of diagnoses, we were not able to analyze this category for statistical significance. Neuromuscular scoliosis has been hypothesized to increase the risk of infection secondary to the presence of paralysis, urinary incontinence and colonization, and seeding with enteric bacteria.<sup>10,20</sup> Often, these fusions include the sacrum/pelvis, with the surgical wound in close proximity to these possible sources of infection.

Intraoperative factors play a significant role in the risk of infection. Operating times lasting more than 5 hours have increased the infection rate.<sup>21,22</sup> Longer and more extensive procedures lead to increased blood loss, and often involve the use of instrumentation.<sup>1,2,10,15,16</sup> In a study of 850 spinal procedures, Wimmer *et al*<sup>13</sup> found that 19 of 22 infections occurred in patients with more than a 1000 cc of blood loss. Operating time for all infected patients did appear to be a significant risk factor. However, when looking at adult patients only, this significance is lost. A similar trend between groups was found when examining the number of spinal segments operated on. The statistical discrepancy between groups for these factors may be related to the increased power of the analysis gained by the addition of the pediatric patients. Compared to previous studies, we did not find blood loss to be a significant risk factor, even after stratifying the results.

In the analysis of intraoperative factors, we also examined the role of revision surgery, instrumentation, and allograft. In contrast to previous studies, we did not find these 3 factors to be statistically significant. These factors were present in high numbers in both the infected and control groups.

Performing procedures in a staged fashion can increase the rate of infection. Staged procedures are performed with the patient under separate anesthesia, generally about 5–7 days apart. This practice was performed most often for complex spinal procedures that may involve increased operating time, blood loss, and surgeon fatigue. Dick *et al*<sup>23</sup> found that staging procedures tend to increase the rate of wound complications, blood loss, and the overall hospital stay. Nutri-

**Table 8. Number of Infecting Organisms in Each Postoperative Infection**

No. of Organisms	No. of Patients
1	25
2	13
3	6
≥4	4



tional depletion also likely plays a significant role. Calculation of the odds ratio revealed a 3-times higher risk for our patient population when a procedure was performed in a staged manner.

Most investigators have found *S. aureus* to be the most common infecting organism.<sup>1,5,9</sup> The majority of our infections were monomicrobial and also involved *S. aureus*. However, microbiologic review revealed that approximately half of the patients had more than one organism and wide diversity of organisms.

Postoperative infection can occur in a sizable number of spinal procedures. The risk of infection is mediated by the presence of patient comorbidities and risk factors. Preoperative modification of these factors can lead to alteration of a patient's overall risk and most likely improve his/her outcomes. Additionally, examination of intraoperative factors showed increased risk with increasing procedural complexity and length. These findings indicate the need for close attention to operative techniques to limit blood loss and operating time. Postoperative vigilance and possibly a lowered threshold for intervention may also be warranted following complex procedures and for high risk patients.

### Acknowledgments

The authors thank Mr. Peter Bacchetti for his detailed and expert statistical analysis.

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## Imaging Corner

# Noncommunicating Cysts and Cerebrospinal Fluid Flow Dynamics in a Patient With a Chiari I Malformation and Syringomyelia—Part II

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Cerebrospinal fluid (CSF) flow dynamics are known to be altered in the foramen magnum region in patients with Chiari I malformations. In particular, it has been postulated that the downward tonsillar displacement hinders the rapid bidirectional CSF passage across the foramen magnum, which normally occurs during each cardiac cycle in response to the pulsatile expansion and contraction of the brain.<sup>1</sup> It has been postulated that this creates enlarged cervical subarachnoid pressure waves that compress the spinal cord and forces CSF to penetrate into the spinal cord, propagating syrinx fluid caudally with each heartbeat. However, the incidence of syrinx formation in patients with Chiari I malformations is quite variable, and this is a reflection of the complexity of this problem.<sup>2</sup>

It has been reported that 3 types of cavitory patterns can be present in syringomyelia.<sup>3</sup> In particular, it has been determined that the following 3 possibilities exist in these cases: (1) dilatations of the central canal can communicate directly with the fourth ventricle; (2) dilatations of the central canal can occur below a syrinx-free segment of the spinal cord; and (3) extracanalicular syringes can originate in the spinal cord parenchyma and not communicate with the central canal. It is also been suggested that the pathophysiology is different in these 3 conditions. For example, communicating central canal syringes appear to be commonly found in patients with hydrocephalus. Noncommunicating syringes are reported to occur in patients with arachnoiditis. Furthermore, it has also been suggested that different treatment strategies of patients with Chiari I malformations and syringomyelia should be applied based on the type of syrinx that is present.<sup>4</sup>

However, it also has been suggested that “noncommunicating” syringomyelia does not really exist, but rather a communication between the syrinx and the fourth ventricle can always be found.<sup>5</sup> There are no de-

scriptions of independent noncommunicating spinal cord syringes, and quantitation of CSF flow through a syrinx before and immediately after surgery has not been studied. We carefully segment the regions of the upper spinal cord in patients with syringomyelia to calculate flow using phase-contrast magnetic resonance imaging (MRI) in the following 3 spaces: subarachnoid space, syrinx cavity, and spinal cord. In this report, we describe a patient with a very unusual syrinx composed of 2 distinct adjacent components that do not communicate.

## Materials and Methods

**Patient History.** The patient is a 30-year-old female with a history of Crouzon syndrome. The patient underwent a craniofacial advancement for the treatment of this disease 10 years previously. Left arm numbness developed in the patient as well as vertigo approximately 10 years before her most recent presentation, and she has noted a progression of the symptoms. A pressure sensation in her neck also developed. The neurologic examination at this presentation was remarkable for mild dysmetria on the left, a mild gait ataxia, and a decrease in light touch perception over the left side of the body and lower third of the face.

**Surgical Treatment.** The patient was placed in the prone position, and a suboccipital craniectomy was performed. The arch of C-1 was subsequently removed and the dura opened widely in a Y shape. A large piece of DuraGen® (Integra LifeSciences Holding, Inc., Plainsboro, NJ) was placed over the defect before closure.

## Phase-Contrast MRI Protocol

**Imaging Protocol.** The phase-contrast MRI studies were performed using a 1.5 Tesla unit (GE Medical System, Milwaukee, WI). MRI was obtained by using a velocity encoded cine phase-contrast pulse sequence with peripheral gating. CSF volumetric flow rates were measured according to a technique previously described.<sup>6,7</sup> A section 4–6 mm thick was imaged with a 12–16 cm field of view, a 256 × 128 or 256 × 160 matrix, and an average of 2 excitations were acquired. Velocity was encoded along the superior to inferior axis with a gradient strength chosen for velocities of interest to be just below the aliasing velocity (velocity corresponding to 180° phase value). CSF flow was measured with a velocity encoding value of 5–9 cm/s. The shortest available repetition time, 18–19 milliseconds, was used to optimize spatial resolution and to minimize low-pass filtering of the temporal waveform caused by data interpolation. The echo time and flip angle were 9 milliseconds and 20°, respectively. The data were interpolated to the maximum number of time points available per cardiac cycle (32) to minimize errors because of secondary resampling.

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Acknowledgment date: March 29, 2004. First revision date: June 17, 2004. Acceptance date: September 7, 2004.

Supported by a grant from the Vanguard Charitable Endowment Program. The manuscript submitted does not contain information about medical device(s)/drug(s).

Foundation funds were received in support of this work. 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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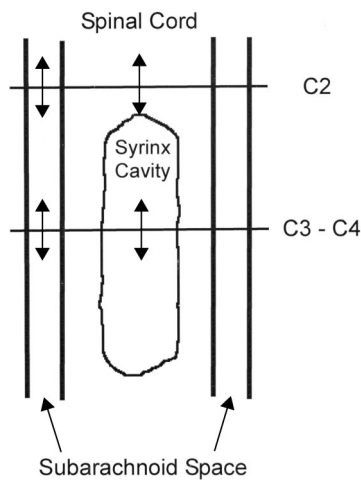


Figure 1. Schematic drawing of the location where measurements are taken.

**MRI Derived Hydrodynamic Parameters.** The oscillatory CSF volume and the pulsatility ratio were also derived from the MRI flow study in 2 regions of interest and within the syrinx cavity (Figure 1). The oscillatory CSF volume is the volume of CSF that flows between the cranium and the spinal canal in each cardiac cycle.<sup>7</sup> Each pixel is proportional to velocity, and, therefore, volumetric flow rates can be obtained by integrating the pixels across a lumen (flow = velocity  $\times$  area). The cord displacement and the volume of CSF that move through the imaging plane (oscillatory CSF volume) were measured at the level above the syrinx (C2) and through a level containing the syrinx (C3–C4), both before and 4 months after surgery.

## Results

The pertinent preoperative MRI studies are illustrated in Figures 2 and 4. The cerebellar tonsils extend approximately 1.0 cm below the foramen magnum, and a large fluid-filled central canal of the spinal cord is shown, which extends throughout the cervical and thoracic spine region. In addition, the ventricular size is normal, and there

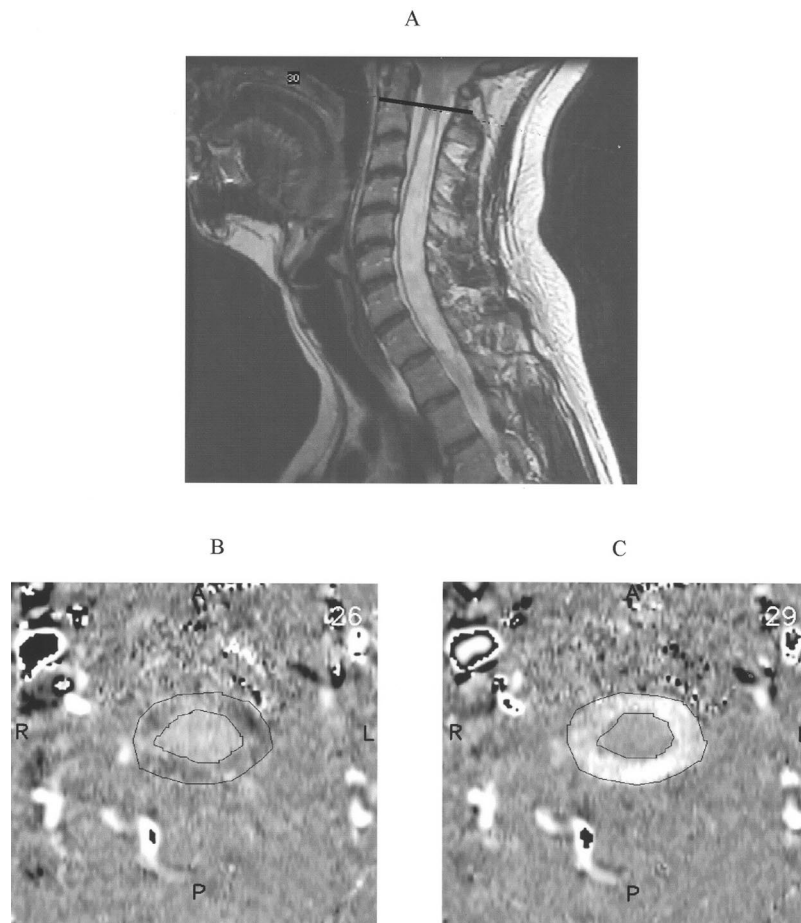


Figure 2. Midsagittal anatomy and the axial encoded images before decompression. **A**, Midsagittal T2-weighted MRI before decompression show that the cerebellar tonsils extend approximately 1.0 cm below the foramen magnum, and a large fluid-filled central canal of the spinal cord extends throughout the cervical and thoracic spine. The line drawn through the region of interest above the syrinx indicates the plane where the subsequent phase-contrast axial images were taken. **B**, Phase-contrast axial MRI during early systole. The downward movement of the spinal cord is shown by the white pixels throughout the inner circle region. The black pixels depict spinal-to-cranial CSF flow. The pixel intensity is proportional to the velocity of flow through the region of interest. Note that no syrinx is visualized in this region of the spinal cord. **C**, Phase-contrast axial MRI during mid systole. The white pixels inside the outlined region of interest depict cranial-to-spinal CSF flow through the subarachnoid space. Note that the downward movement of the spinal cord occurs in early systole, while the peak of CSF flow through the subarachnoid space takes place in mid systole.

**Table 1. Oscillatory CSF Volume and Cord Displacement During Each Cardiac Cycle at the C2 and C3–C4 Levels**

	Preoperatively	Postoperatively
Cord displacement during each cardiac cycle at C2 level (mm)	1.2	0.45
Oscillatory CSF volume through subarachnoid space at C2 level (ml)*	0.53	0.56
Oscillatory CSF volume through subarachnoid space at C3–4 level (ml)†	0.30	0.45
Oscillatory CSF volume through syrinx at C3–4 level (ml)‡	0.121	0.023

\*Volume of CSF that flows in each cardiac cycle between the cranium and spinal canal at the C2 level.

† Volume of CSF that flows in each cardiac cycle between the cranium and spinal canal at the C3–C4 level.

‡ Volume of CSF that flows through the syrinx at the C3–C4 level during each cardiac cycle.

is no evidence for hydrocephalus in this patient. Using phase-contrast MRI, the cranial-to-spinal CSF flow is white, while upward CSF flow toward the cranial cavity is black. In the studies taken at the level of C1, there is no evidence for a syrinx cavity (Figures 2B, 2C). However, there is evidence of significant movement of the spinal cord during each cardiac cycle (Table 1, Figure 3B). Although

the T2-weighted axial MRI image (Figure 4B) shows a large cystic cavity with inhomogeneous signal intensity, the phase-contrast MRI taken at the level of C4 (Figures 4C, 4D) show 2 distinct cystic cavities within the spinal cord during both systole (CSF flow away from cranial cavity in subarachnoid space) and diastole (CSF flow toward brain in subarachnoid space). No communication was observed between the oscillatory CSF flow of the syrinx cavity and the fourth ventricle.

In addition, the spinal cord is clearly swollen, and, therefore, the CSF flow through the subarachnoid space is uneven. It is also apparent that the pattern of CSF flow through the syrinx is different than that noted in the subarachnoid space during each cardiac cycle. In particular, in late systole there is residual cranial-to-spinal CSF flow in the subarachnoid space, while there is marked upward CSF flow through the two cystic cavities (Figure 4D). Also, CSF flows upward through the subarachnoid space during mid diastole, yet no flow is detected through the syrinx at this time (images not shown).

Following surgery, the patient had a temporary worsening of her gait ataxia, but several weeks later, the gait was relatively normal. The dysmetria present on the left side resolved quickly after surgery. The numbness in-

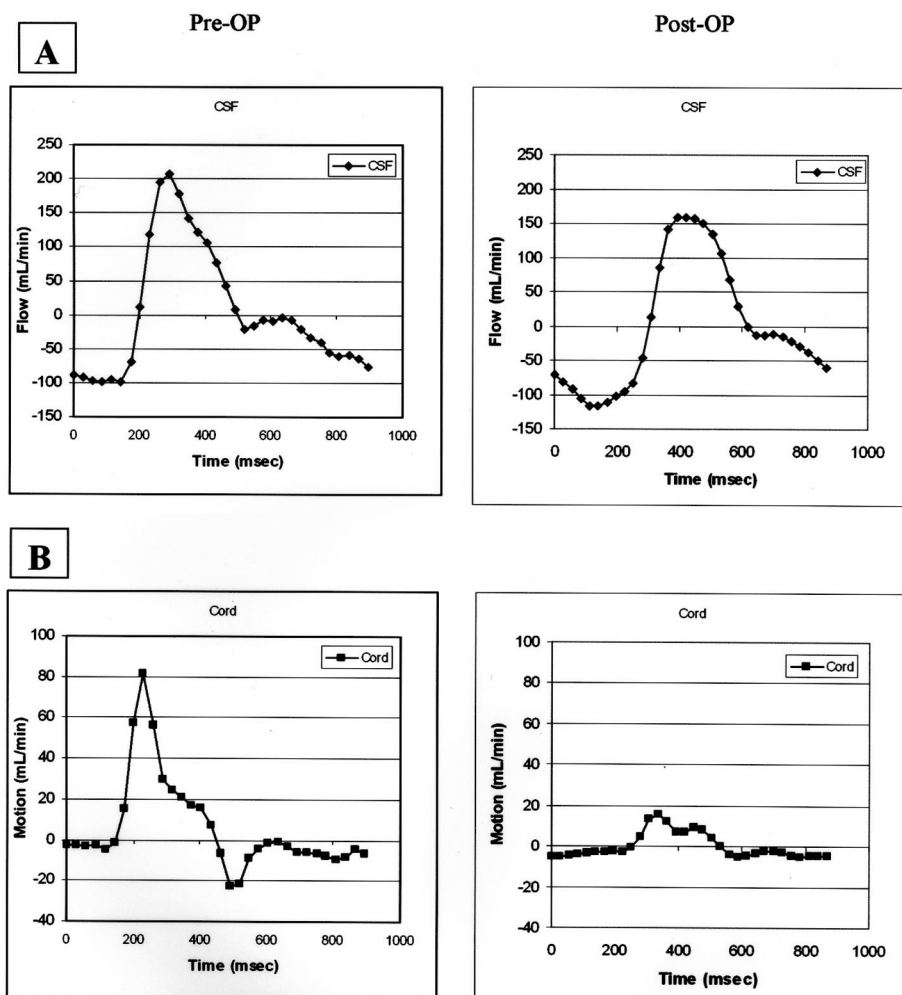


Figure 3. **A**, CSF volumetric flow waveforms through the subarachnoid space before (pre-op) and 4 months after (post-op) surgery in the region of interest above the syrinx outlined in Figure 2. Note the peak CSF flow rate during the preoperative period is somewhat higher than the flow after surgery secondary to the outflow obstruction. **B**, Spinal cord movement in region of C2. Note that the movement of the spinal cord is markedly decreased in this region following surgical decompression.



Figure 4. **A**, Midsagittal T2-weighted MRI before decompression. The line is drawn through the region of interest through the syrinx cavity where the subsequent axial images were taken. **B**, Axial T2-weighted MRI shows a large syrinx with inhomogeneous signal intensity. **C**, Phase-contrast axial MRI during systole shows 2 distinct cyst cavities that have been outlined (see arrows). The white pixels inside the region of interest depict cranial-to-spinal CSF flow. In addition, there are uneven CSF velocities in the cervicospinal subarachnoid space. **D**, Phase-contrast axial MRI during late systole again shows two distinct cyst cavities (see arrows). The black pixels inside the region of interest depict reverse or upward CSF flow, while the subarachnoid CSF flow is downward.

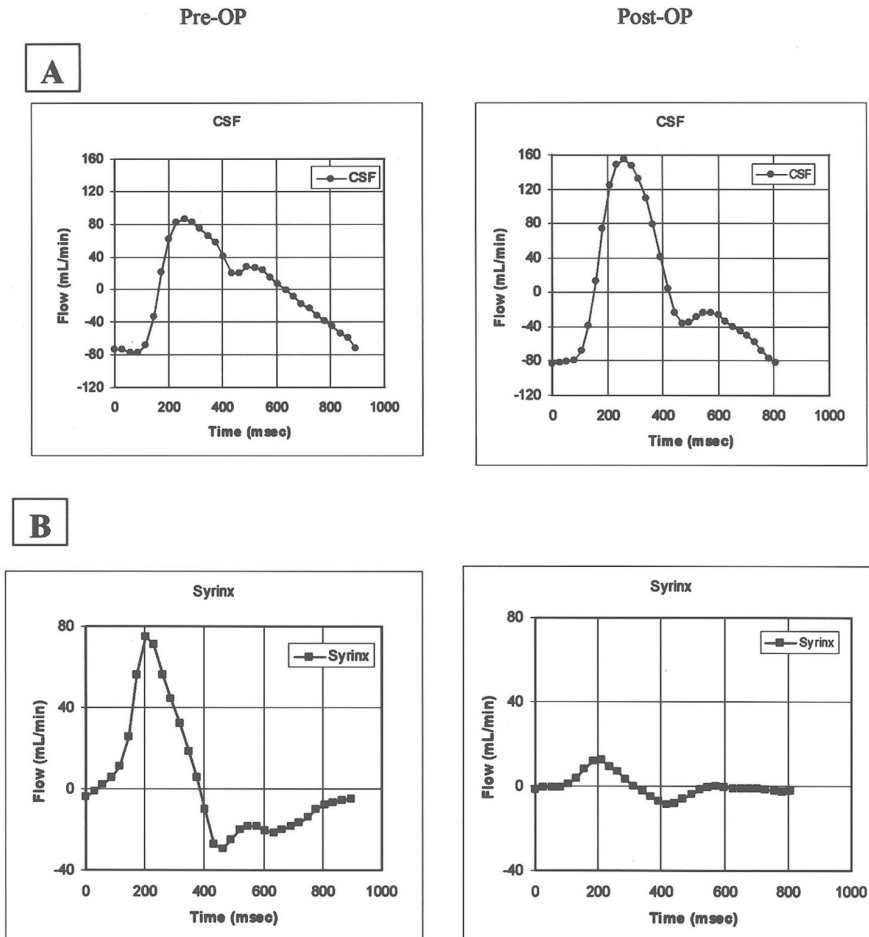
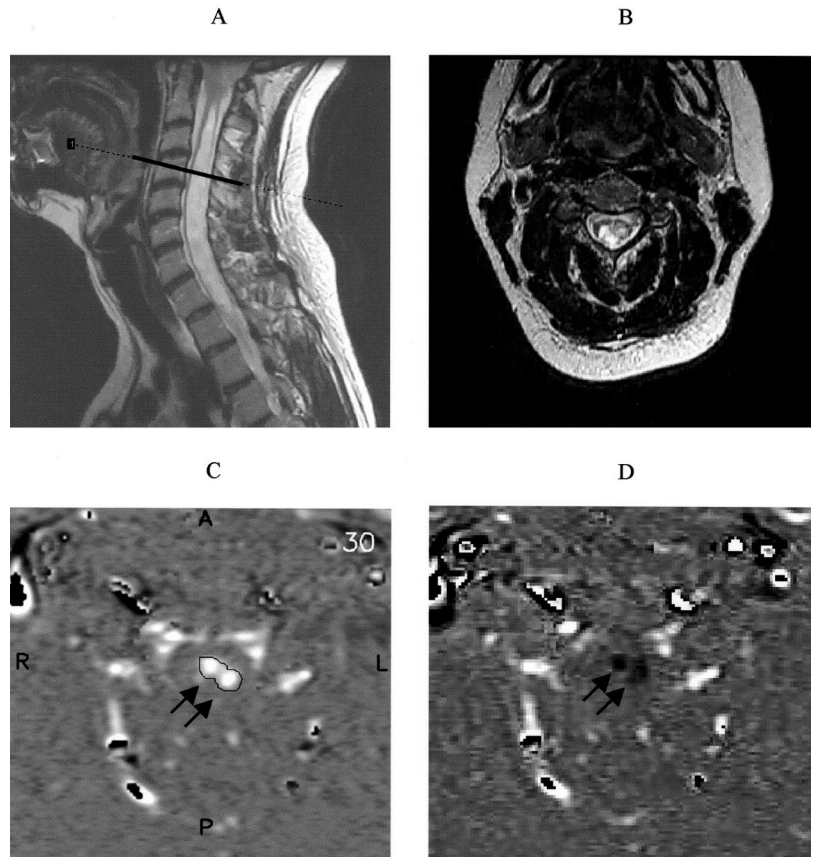
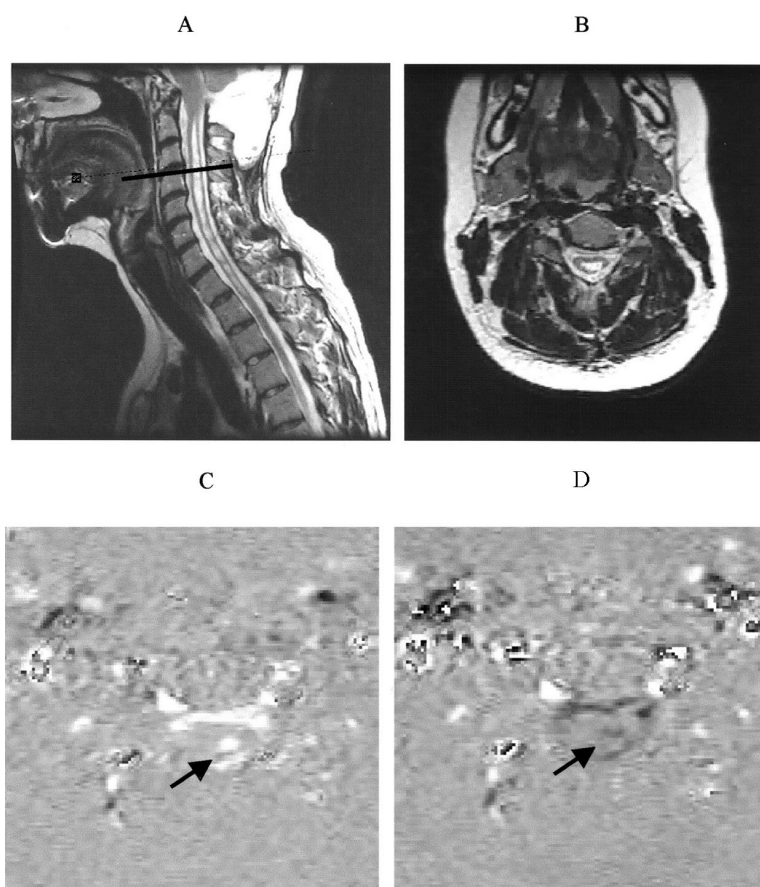


Figure 5. CSF flow waveforms through the subarachnoid space (**A**) in comparison to total CSF flow through the syrinx cavities (**B**). Note that there is a dramatic decrease in CSF flow through the remaining syrinx after surgical decompression. Also note that the CSF flow rate through the enlarged subarachnoid space is significantly higher after surgery in comparison to the flow rate measured before surgery. In all of the CSF waveform studies, the peak of flow through the syrinx cavity (or two cavities in the pre-operative study) was at a time before the peak flow through the subarachnoid space region.

Figure 6. **A**, Post-decompression midsagittal T2-weighted MRI taken 4 months following surgery. Note the marked decrease in size of the syrinx after the foramen magnum was decompressed. The line is drawn through the region of interest similar to the level described in Figure 2. **B**, Axial T2-weighted MRI shows residual syrinx. **C**, Phase-contrast axial MRI during systole now shows only one cyst cavity (arrow). The direction of CSF flow in both the syrinx and subarachnoid space is in a cranial-to-spinal direction (white pixels). **D**, Phase-contrast axial MRI during diastole also illustrates only one cyst cavity (arrow). The direction of CSF flow in both the syrinx and subarachnoid space is an upward direction (black pixels).



volving the left side of the body improved substantially, but the patient noted significant numbness of the right leg after surgery that partially resolved within several months. The patient also had fairly severe headaches after surgery, and it took several weeks for the headaches to decrease. A postoperative MRI was obtained 4 months after surgery (Figure 6). The sagittal study revealed that the syrinx had markedly decreased in size (Figure 6A). The CSF flow through the subarachnoid space increased dramatically after surgery in the region of the spinal cord containing the syrinx (Table 1, Figure 5A). Clearly, the swollen spinal cord before surgery resulted in a restriction of CSF flow through the subarachnoid space, and that caused a pressure difference in CSF flow between the subarachnoid space above and through the syrinx region (Figures 3A, 5A). There was also a significant decrease noted in the spinal cord movement after surgery in comparison to the preoperative study (Figure 3B, Table 1).

The most marked finding was that the postoperative phase-contrast study revealed only one cyst cavity (Figure 6C, D), and there was a dramatic decrease in oscillatory CSF flow through the remaining cyst (Figure 5B, Table 1). Before surgery, it was documented that there was relatively equal pulsatile flow in both syrinx cavities. It should also be noted that following surgical decompression, once again the CSF flow through the remaining syrinx component showed a different time course than

the CSF flow through the subarachnoid space. In particular, upward spinal-to-cranial CSF flow through the syrinx cavity was noted during late systole during which there was downward flow of CSF through the subarachnoid space (images not shown). Some residual pulsatility of CSF flow through the remaining syrinx persisted 4 months postoperatively (Figure 5B, Table 1). Clearly there was a gradual decrease in CSF pulsating or being displaced into the syrinx cavity during each cardiac cycle throughout the postoperative period.

It should be noted that at this time, the patient continued to have some lower body numbness, although her gait was normal, and the vertigo has completely resolved. In addition, the patient had 1 or 2 episodes each day lasting less than one minute, involving fairly severe pain in the upper back region with radiation to the upper arms. There is a collection of spinal fluid or old blood noted in the region of the dissection cavity external to the dural patch in both postoperative studies (Figure 6), but the phase-contrast MRI study of this region, which is very sensitive for detecting fluid flow, shows that this fluid is stagnant and does not communicate with the subarachnoid space.

## ■ Discussion

A motion sensitive MRI technique (cine phase-contrast) was used in this case to visualize and quantitate CSF flow through the foramen magnum region before and after surgery in a patient with a Chiari I malformation and

syringomyelia. In this particular case, phase-contrast MRI before surgery documented the presence of a cystic cavity throughout the entire spinal cord containing 2 distinct adjacent subcompartments. Following standard foramen magnum decompression, there was improvement in symptoms, but only one of the cysts resolved, while the other cyst remained. This is an unusual case of compartmentalization of a syrinx cavity that has not been noted in our large series of patients with syringomyelia. Although insufficient decompression or postoperative arachnoid adhesions at the cisterna magna region as measured by CSF flow studies using cine phase-contrast MRI have been suggested as the cause of surgical failure,<sup>8</sup> such mechanisms clearly are not an issue in this case.

Obstruction of the foramen magnum because of herniation of the cerebellar tonsils causes an abrupt systolic downward displacement of the spinal cord, and, in one study, this resulted in the impaired recoil of CSF during diastole, although CSF pulsations during systole were unchanged.<sup>9</sup> In contradistinction, another study showed that impaired systolic and unaltered diastolic CSF flow pulsations immediately below the foramen magnum are present in this patient population, and the systolic flow pulsations improve following surgical decompression.<sup>10</sup> However, our own preliminary studies have shown that in some patients, surgical decompression of the obstructed foramen magnum may not result in a change in the amount of CSF that flows back and forth with every cardiac cycle.<sup>11</sup> This result was also true in this case. In particular, the CSF flow through the subarachnoid space at the C2 level remained essentially the same at 4 months in comparison to the CSF flow measured initially in this region (Table 1). However, the time course for the CSF flow was more prolonged before surgery secondary to the obstruction in this region because of the herniated cerebellar tonsils (Figure 3A). Also, the CSF flow is more uniform through this region after surgery. What does improve is the increased oscillatory flow in the subarachnoid space around the syrinx cavity (Figure 5A, Table 1). It is clear that resolution of the syrinx allows more CSF to propagate down the spinal canal during each cardiac cycle.

Phase-contrast MRI studies have been used to document the evolution of syringomyelia associated with Chiari I malformations. It has been hypothesized that spinal cord compression at the foramen magnum results in caudal propagation of syrinx fluid, with each cardiac cycle leading to syrinx progression.<sup>1</sup> It has also been shown that CSF flow from perivascular spaces into the central canal is dependent on arterial pulsations, suggesting that arterial driven CSF flow may be the impetus for the expansion of a syrinx.<sup>12</sup> However, it would appear in this case that a different mechanism is responsible for the development of the syrinx because CSF flowed in a spinal-to-cranial direction within the syrinx during late systole during which the direction of CSF flow in the subarachnoid space was in a cranial-to-spinal direction. Each CSF compartment in this case had a unique re-

sponse to decompression, and some residual pulsatility existed after 4 months in the one remaining syrinx cavity. In light of the fact that the pulsatility of the remaining cyst remained small over several months following surgical decompression of the foramen magnum, and the residual symptoms were mild, it was thought that shunting the remaining syrinx cavity would not be beneficial. The persistent, small residual pulsatility in the one remaining syrinx is somewhat in contradiction to previous reports that pulsatility subsides within a syrinx cavity several months after decompression of the foramen magnum.<sup>13</sup>

Following surgical decompression, the resistance to CSF flow is reduced in the subarachnoid space surrounding the spinal cord containing the cyst. In particular, there is less difference in the oscillatory CSF flow between the subarachnoid space above the syrinx in comparison to the region surrounding the spinal cord containing the syrinx cavity (Table 1). This results in more even CSF flow throughout the cervical spine following surgical decompression of the foramen magnum. There is a dramatic change in the CSF flow through the syrinx cavity associated with a marked decrease in spinal cord movement during each cardiac cycle following surgery. Clearly, there are different mechanisms involved in the driving forces of CSF flow through a syrinx cavity in comparison to the forces involved in CSF flow through the normal channels of the subarachnoid space around the spinal cord.

## ■ Conclusions

In this unique case of a patient with a Chiari I malformation and syringomyelia, decompression of the foramen magnum was successful from a clinical standpoint, and was associated with a reduction in the degree of spinal cord displacement and volumetric CSF flow through the syrinx. A decrease in the resistance of CSF flow through the subarachnoid space of the spinal cord containing the syrinx following surgery resulted in more even CSF flow throughout the entire spinal cord region. Only 1 of the 2 cystic cavities resolved following surgical decompression, indicating that the 2 components of the cyst represent distinct compartments. A MRI measure of transcranial CSF flow may lead to a better understanding of the pathophysiology of Chiari malformations and should prove to be an important diagnostic tool for guiding the treatment of patients with Chiari I malformations.

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# Letters

To the Editor:

Re: Konstantinou DT, Chroni E, Constantoyiannis C, et al. Klippel-Feil syndrome presenting with bilateral thoracic outlet syndrome. *Spine* 2004;29:E189–E192.

Konstantinou *et al* describe the case of a 25-year-old woman with concomitant Klippel-Feil syndrome (KFS) Type 1 and thoracic outlet syndrome (TOS). Notwithstanding their substantial work, we have a few comments pertaining to their report.

First, with regard to the diagnosis of TOS, we do agree that it is mainly established clinically and that their patient really suffered from TOS. However, the way they mention the findings of TOS in the introduction and their relevant clinical findings do not seem to correspond, whereas just the opposite, *i.e.*, the muscle strengths of the patient were normal but the reflexes were diminished, is the case.

The other two points we could not have substantiated in the physical examination of the patient were the blood pressure measurements selectively carried out from the brachial, ulnar and radial arteries; and the so-called 2-minute-hyperabduction maneuver. We question the technique of the former and the reason for not being for 3 minutes if it were to be the Roos test for the latter.

Given the lack of evidence for a neurogenic lesion in the electromyographic sampling of the upper extremity muscles, the reduction of F wave persistence solely does not seem to rationalize the diagnosis of a true neurogenic TOS in their patient. It is also not clear to us why the dynamic F wave studies were performed on the median nerves but not on the ulnar nerves, where one could possibly expect to observe more pertinent changes. Moreover, the authors attribute the F wave anomalies to an ischemic-induced transient conduction block of motor nerve fibers because of the compression of the brachial plexus while the arms were elevated. However, noteworthy in the physical examination of the patient was that she also encountered arterial compromise during the same maneuver. Thus, their assumption would be debatable.

According to the classification of TOS in the review paper that the authors have mainly addressed,<sup>1</sup> we think that the diagnosis of disputed neurogenic and vascular TOS would be much more sound for their patient. Such patients really do experience fatigue temporarily, but the muscle strengths are not affected.<sup>2</sup>

Last, the authors have drawn attention to the rarity of KFS and therefore the unknown coincidence of cervical ribs, whereas it is mentioned to be 12% to 15% in the literature.<sup>3</sup> On the contrary, we must say that true neurogenic TOS, with overt neurologic findings and without any vascular compression, is extremely rare,<sup>4</sup> even much more so than the authors indicate for KFS.

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## In Response:

We thank Dr. Özçakar *et al* for their interest in our case of Klippel-Feil syndrome that caused bilateral thoracic outlet syndrome (TOS). In response, we wish to provide the following facts.

1. Muscle weakness does not necessarily accompany reduction of tendon reflexes, particularly when, as in our case, sensory disturbances are the apparent reason for reflexes' changes.
2. In respect to the hyperabduction maneuver, the patient's condition was severe enough that the maneuver brought up her usual symptoms and diminished the radial pulse within 2 minutes. Continuation of this test for another minute, which in any case was unbearable for the patient, would add nothing to the diagnosis.
3. F wave measurement is a well-established method in detecting motor conduction abnormalities in cases

where conventional techniques had failed.<sup>1</sup> The significance of the persistence of F waves is particularly apparent in detecting conduction block in the proximal nerve segments, such as in TOS, which are unreachable by direct stimulation.<sup>2</sup> Both median and ulnar nerve F waves were studied, but median abnormalities were more severe. This was not unexpected since motor conduction slowing and muscle weakness are typically prominent in the thenar eminency while sensory disturbances preferentially involved the ulnar territory.<sup>3</sup> A mechanism of ischemic-induced transient conduction block demonstrated by dynamic F wave study has been previously suggested for an analogous condition in the lower limbs.<sup>4</sup> Only neural, not arterial, dysfunction would cause F wave changes.

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cidence of TOS has not been clearly established. Perhaps, sophisticated techniques, like dynamic F wave study, will disclose true neurogenic cases among the presumed "disputed" neurogenic TOS.

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# Pedicle Screw Placement in the Thoracic Spine

## A Comparison of Image-Guided and Manual Techniques in Cadavers

Robert A. Hart, MD,\* Brenden L. Hansen, BS,\* Marie Shea, MS,\* Frank Hsu, MD,† and Gregory J. Anderson, PhD†

**Study Design.** A cadaveric study comparing image guidance technology to fluoroscopic guidance as a means of pedicle screw placement in the thoracic spine, using a unique starting point for screw placement.

**Objective.** To assess accuracy of thoracic pedicle screw placement using image guidance *versus* fluoroscopic guidance for screw insertion.

**Summary of Background Data.** While use of pedicle screws in the thoracic spine has been increasing, its adoption has been slower than for the lumbar spine, reflecting concern regarding possible vascular or spinal cord injury due to screw malplacement. Given these risks, efforts to improve the accuracy of thoracic pedicle screw placement remain appropriate. Stereotactic guidance has been applied in other aspects of spinal surgery to improve the accuracy of instrumentation placement.

**Methods.** Pedicle screws were placed in the thoracic spines of eight cadavers, using either a stereotactic guidance or a manual, fluoroscopically guided technique. A slightly more superior and lateral starting point from prior descriptions was used. Each cadaver was instrumented with pedicle screws in the upper thoracic (T1–T2), middle thoracic (T4–T7), and lower thoracic (T9–T10) regions. In the upper and middle thoracic regions, screws with a 4.0-mm shank diameter were used while in the lower thoracic region a shank diameter of 4.5 mm was used. Postinstrumentation CT scans, followed by anatomic dissections, were used to evaluate screw exit rates and orientation relative to the pedicle axis. Exit rates for the two techniques and the effect of vertebral level on exit rate were compared using a  $\chi^2$  analysis. The effect of pedicle diameter was tested using a Pearson correlation coefficient.

**Results.** No significant differences in the overall exit rates or orientation were found between the two techniques. There were significant differences in exit rates between the middle (47%), compared with the upper (9%) and lower (16%) thoracic regions, respectively ( $P < 0.001$ ). A significant correlation between pedicle diameter and exit rate was also found ( $P < 0.0001$ ).

**Conclusion.** Our study showed no significant differences in the overall exit rates between the two techniques. Image guidance may increase confidence of sur-

geons with limited experience in thoracic pedicle screw placement. Successful placement of screws within the pedicle varies with the anatomic diameter of the pedicle itself. Concerns regarding accuracy of screw placement should be greatest in the middle thoracic vertebrae (T4–T7), where pedicle diameters are smallest and proximity of the great vessels is nearest.

**Key words:** stereotactic guidance, thoracic spine, pedicle screws, cadaver study. **Spine 2005;30:E326–E331**

Pedicle screw fixation of the lumbosacral spine has been very successful for many clinical indications and is currently widely used. Pedicle screws provide mechanically stronger constructs than fixation techniques such as wiring or hook-based systems, and can be used even when the posterior elements of the spine are absent or injured.<sup>1–4</sup> The safety of lumbosacral pedicle screws has been shown to be comparable to other means of spinal fixation, leading to FDA approval of their use.<sup>5</sup> This high level of safety and efficacy has been established despite a significant and well-documented error rate in the placement of these screws.<sup>6,7</sup>

In comparison to the lumbosacral spine, reported experience with thoracic pedicle screws has been more limited. This may reflect concerns regarding the safety of screw placement in the thoracic spine, as well as the more limited indications for instrumentation of the thoracic spine. The smaller diameter of the thoracic pedicles and proximity of the spinal cord and great vessels increase the potential risks of screw malposition in the thoracic spine, especially on the left side of the midthoracic region where the aorta lies in intimate contact with the vertebrae.<sup>8–15</sup>

Despite the acknowledged risks, pedicle screw instrumentation in the thoracic spine does offer several advantages. Mechanically stronger fixation may allow for better correction of spinal deformity and reduces the chance of loss of fixation, which can occur with hook-based instrumentation.<sup>3,4,16–19</sup> In addition, fewer vertebral motion segments can be included in the fusion, and risks of nonunion may be reduced.

Image-guidance technology has been successfully demonstrated in several spinal procedures.<sup>20–31</sup> This technique relies on the correlation of preoperative computed tomographic images with the actual surgical anatomy. These systems provide intraoperative information to the surgeon regarding instrumentation starting point, orientation, and size relative to anatomic dimensions. Image guidance technology may be one means of increasing the accuracy of pedicle screw fixation in the thoracic spine.

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The device(s)/drug(s) is/are FDA-approved or approved by corresponding national agency for this indication.

Corporate/Industry funds were received in support of this work. 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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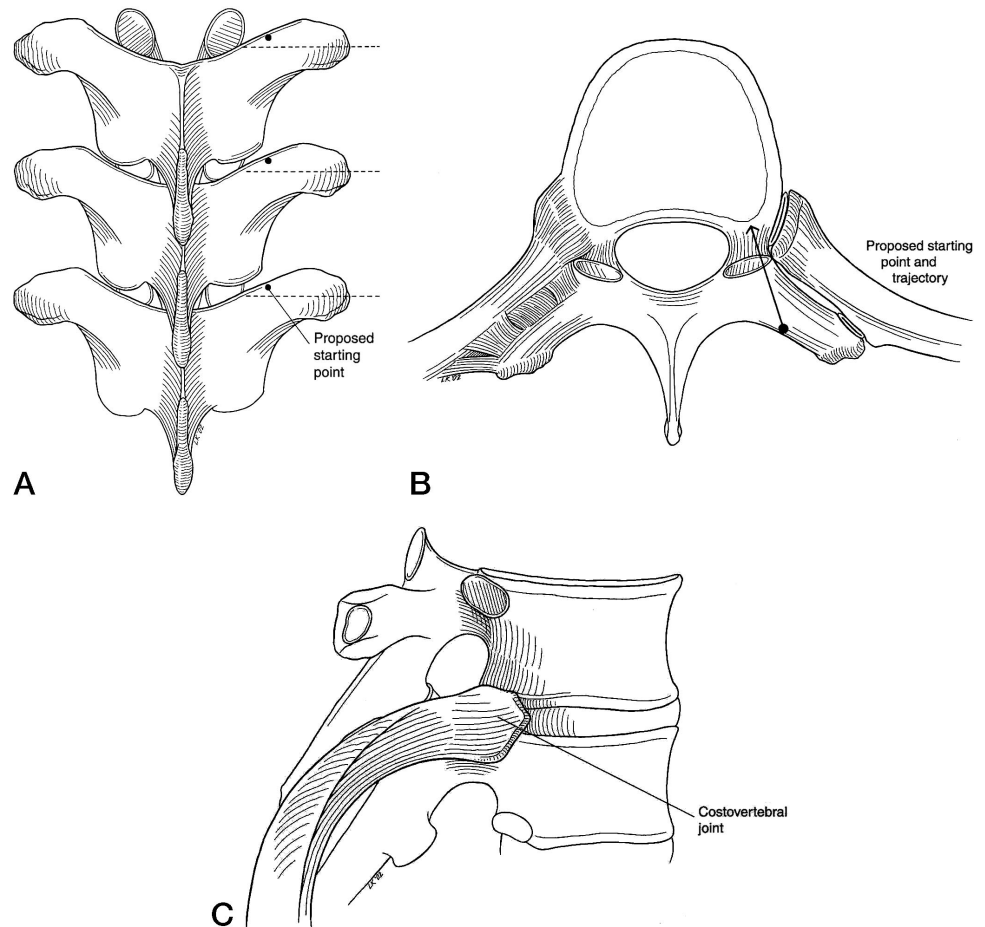


Figure 1. **A**, Posterior view of the proposed starting point for the placement of the thoracic pedicle screw. **B**, Lateral view of the thoracic vertebrae showing the coverage of the pedicle by the rib head at the costovertebral joint. **C**, Superior view of the proposed starting point and trajectory for the placement of the thoracic pedicle screw.

The anterior costo-vertebral joints are located on the lateral aspect of the vertebral body adjacent to the upper half of the pedicle.<sup>32</sup> Lateral screw breakout at this level should therefore be safe, as the rib heads and the joint capsule will cover the pedicle screw. Given the small pedicle diameters, particularly in the middle thoracic levels (T4–T8), acceptance of lateral pedicle exit at the level of the costo-vertebral joint may increase the safety of pedicle screw placement.

We hypothesized that image guidance would improve accuracy of pedicle screw placement over manual screw placement techniques, and that choice of a superolateral starting point, with acceptance of lateral pedicle breakout at the level of the rib head, would reduce the risk of spinal cord and great vessel injury. This study tested these hypotheses by comparing image-guided and fluoroscopically guided placement of thoracic pedicle screws in human cadavers.

## Methods

The thoracic cages and spinal columns of eight cadavers were harvested intact. All cadavers underwent computed tomographic (CT) scanning from T1 to T10 to rule out structural lesions of the spine and to evaluate the diameter and orientation of the pedicles. Two independent reviewers measured diameters of pedicles bilaterally at each level from the CT scans using digital calipers, and the average of these measurements was recorded as the pedicle diameter.

Cadavers were randomly assigned to one of two instrumentation groups. In four cadavers, image guidance technology (Stealth, Sofamor-Danek, Memphis, TN) was used for screw placement. In the remaining four cadavers, a fluoroscopically guided manual technique was used. Preoperative CT scans of cadavers assigned for image-guided screw placement were performed using 1-mL cuts to allow use of image guidance software.

Three groups of vertebrae were developed based on spinal

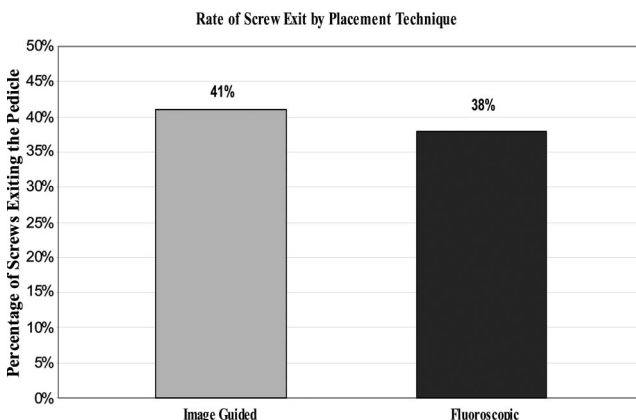


Figure 2. Comparison of thoracic pedicle screw exit rates for image guided and fluoroscopically guided techniques.

## Rate of Screw Exit by Vertebral Level

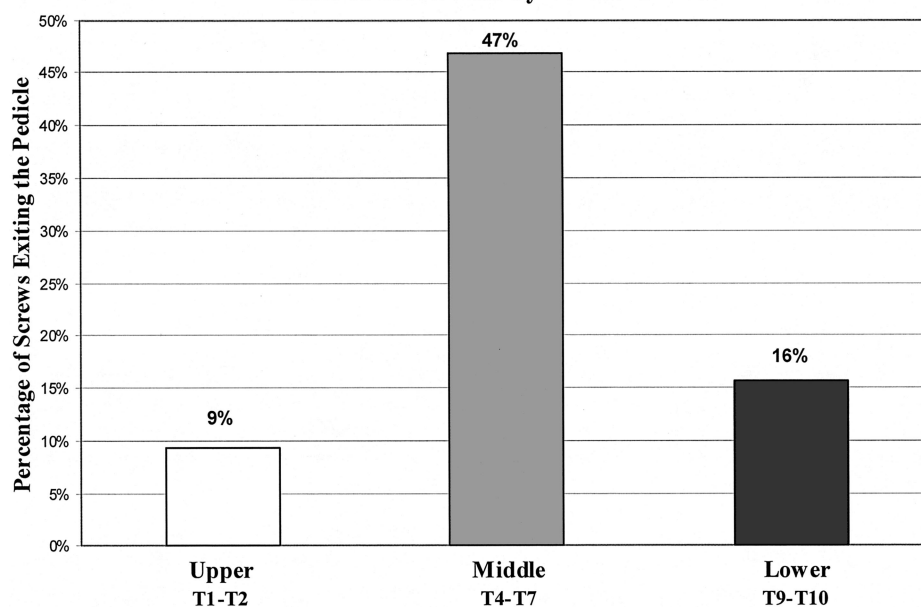


Figure 3. Comparison of thoracic pedicle screw exit rates for the upper, middle, and lower thoracic spine.

level. The T1–T2, T4–T7, and T9–T10 vertebrae were chosen to represent the upper, middle, and lower thoracic spine, respectively; the T3, T8, T11, and T12 vertebrae were not instrumented. Screws with a 4.0-mm shank diameter were placed in the upper and middle thoracic vertebrae while 4.5-mm diameter screws were used in T9 and T10; all screws were 30 mm in length.

Surgical technique included resection of the posterior skin and paraspinous musculature to allow exposure of bony elements similar to that performed for a standard posterior surgical approach. Laminotomy of all instrumented vertebrae was performed for both the image-guided and manual groups. The medial wall of the pedicle was palpated in the spinal canal using a Penfield number four elevator before and following screw placement. Pedicles were sounded using a 3.2-mm power drill rather than a hand-held probe. All pedicle screws were placed by the senior author (R.A.H.).

Registration of vertebral levels for cadavers undergoing image-guided screw placement was performed using four identified reference points (point merge technique) and multiple non-

identified points (surface merge technique). No fluoroscopic imaging was used in the image-guided group; starting points and orientation of screws were determined from the computer guidance images. Screw placement in the manual group was performed using lateral, anteroposterior, and axial fluoroscopic views of the pedicles.

Pedicle screws were placed using a starting point several millimeters lateral and slightly cranial to that proposed by some authors.<sup>2,14,17,18,33,34</sup> As the ribs articulate with the cranial half of the pedicles, this starting point allows coverage of screws exiting the lateral pedicle wall by the rib heads (Figure 1). This trajectory augments the surface area of bone available for screw placement, allowing screw coverage lateral to pedicles of insufficient diameter to accommodate standard pedicle screws.

Following instrumentation, all cadavers underwent CT scans to assess accuracy of screw placement. Perforation of the pedicle was scored as present or absent for all screws by two independent reviewers. Perforations were classified as medial or lateral based on the primary direction of exit.

All cadavers were then sectioned in the sagittal plane through the midline of the vertebral canal and the neural elements were removed. Ribs were disarticulated and screw perforations were verified for location and extent. Screw perforations were assessed to determine whether an exit registered on postinstrumentation CT scans were true anatomic perforations and whether the screw exit actually put vital structures at risk. Screws exiting lateral to the pedicle at the level of the rib head but not exposed beyond the bony surface of the rib/vertebra complex were considered safe. Exit rates for stereotactic guidance *versus* manual placement techniques were compared using a  $\chi^2$  analysis. The effect of pedicle diameter and vertebral level on exit rates were tested using a Pearson correlation coefficient and a  $\chi^2$  analysis, respectively.<sup>35</sup>

## Results

A total of 128 pedicle screws were placed. Based on postinstrumentation CT scans, a total of 52 of 128 screws exited the pedicle, for an overall rate of screw exit of 40%.

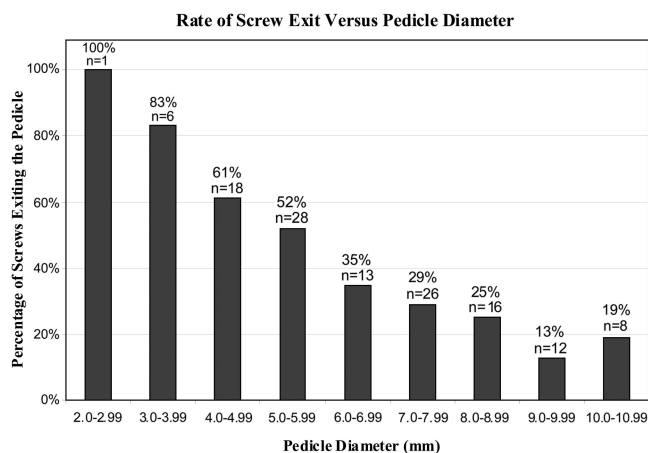


Figure 4. Thoracic pedicle screw exit rates (in percent) *versus* pedicle diameter. "n" Refers to the number of screws placed in pedicles of a given diameter.

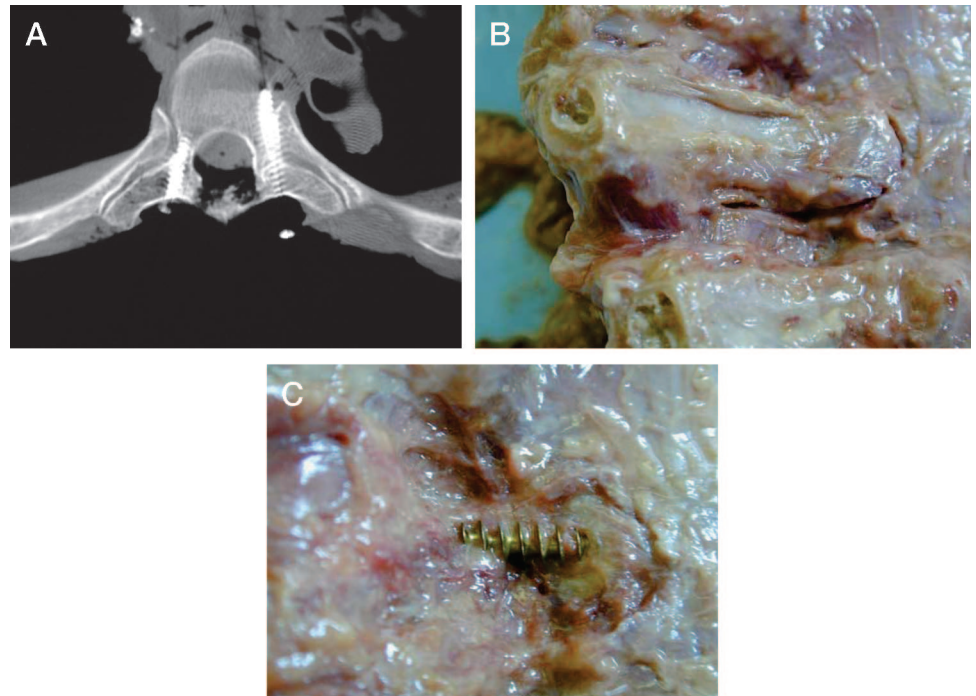


Figure 5. **A**, Lateral pedicle exit at the level of the rib head and costovertebral joint. **B**, Anatomic dissection demonstrating lack of pedicle screw exit with the rib head in place. **C**, Following removal of rib head, exiting pedicle screw is visualized.

The rates for the image-guided and manual screws were 41% and 38%, respectively (Figure 2). These differences were not significantly different ( $P > 0.5$ ).

A statistically significant difference was found in exit rates between vertebral levels (Figure 3). The rate of exit at the middle thoracic levels was 47%, while the rates for the upper- and lower-thoracic spines were 9% and 16%, respectively. While the middle thoracic exit rate was significantly greater than both upper and lower levels ( $P < 0.001$  for both comparisons), there was no significant difference between the upper and lower levels ( $P > 0.5$ ).

Exit rates did correlate with pedicle diameter to a statistically significant degree ( $R = 0.9650$ ,  $P < 0.0001$ ). This correlates with the variation of exit rates between vertebral levels, as the pedicle diameters are smallest at the midthoracic vertebrae. The mean pedicle diameters and standard deviations were  $8.4 \pm 1.7$  mm,  $5.7 \pm 1.6$  mm, and  $7.1 \pm 1.5$  mm for the upper (T1–T2), middle (T4–T7), and lower (T9–T10) thoracic vertebrae, respectively (Figure 4).

Of the 52 screws that exited the pedicle, a total of 47 exited laterally based on CT review. Anatomic dissections demonstrated that 43 or 47 lateral pedicle exits occurred at the level of the rib head and did not threaten critical structures (Figure 5). Four laterally placed screws were felt to place either nerve roots or great vessels at risk (Figure 6). Five screws were felt on CT to demonstrate medial extrusion. All five screws that appeared to perforate medially on CT scans were found on anatomic dissection to have expanded or minimally breached the wall, without putting the spinal cord at risk (Figure 7).

## Discussion

Pedicle screw fixation offers several advantages over hook or wire-based fixation, including higher stiffness

and pull-out strength than hook-based instrumentation.<sup>1,4,16,19,36</sup> These advantages have led to widespread adoption of pedicle screw fixation in the lumbar spine for multiple clinical applications, including deformity, tumor, infection, fracture, and degenerative conditions.

The anatomy of the thoracic spine differs in several respects from the lumbar spine. In addition, there are regional variations within the thoracic spine in the dimension and orientation of vertebral pedicles. Scoles *et al*<sup>12</sup> measured the morphology of adult spines and determined that the minimal pedicle diameters varied from 3.0 to 3.5 mm at T6, to 6.4 to 7.3 mm at T1 and 7.2 to 7.4 mm at T12. Other authors have confirmed these values.<sup>2,10,11,5,34,37</sup>

Given these diameters, the pedicle in the midthoracic region will often be too small to accommodate standard commercially available pedicle screws. It is therefore not surprising that high penetration rates have been reported in several prior studies. Cinotti *et al* reported a 16% to 24% exit rate, depending on the starting point used.<sup>17</sup> Vaccaro *et al* reported a 41% overall exit rate in cadavers with a 23% rate of medial intrusion and recommended against the use of pedicle screws in the thoracic spine.<sup>34</sup>

The presence of the costo-vertebral articulations offers an expansion of the bony surface area available for screw placement.<sup>2,32</sup> Lateral exit from the pedicle with subsequent reentry into the vertebral body has been recommended based on the articulation (“in-out-in” technique).<sup>33</sup> We found the acceptance of lateral pedicle exit resulted in safe screw placement in most cases. Using both manual and image-guided techniques, we recorded no significant medial intrusions, and only 4 of 47 laterally placed screws were felt to place the great vessels or nerve roots at risk.



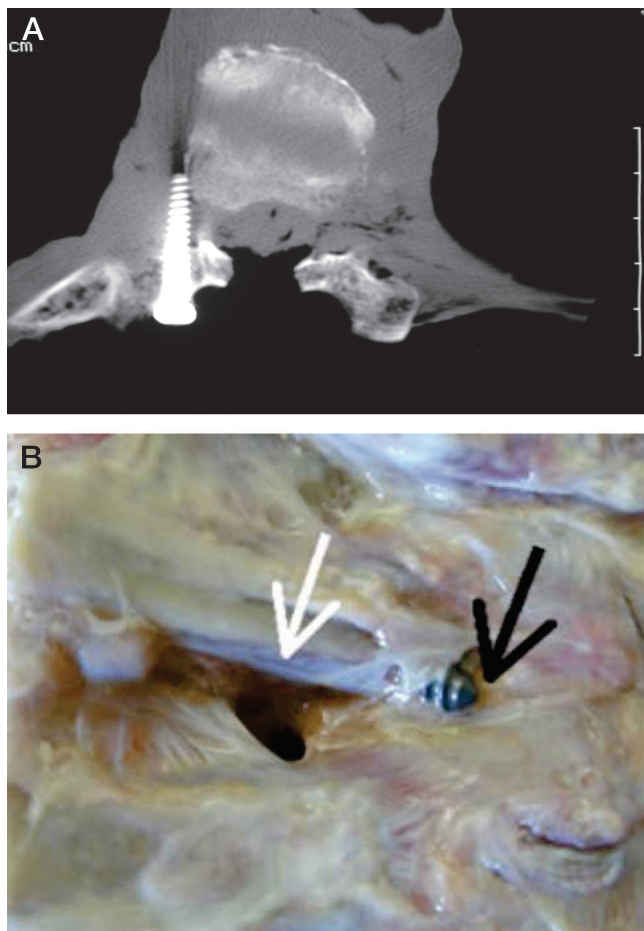


Figure 6. **A**, Laterally and inferiorly placed screw with potential impingement on nerve root and vascular structures. **B**, Anatomic dissection demonstrating inferior intrusion into foramen (white arrow) and anterolateral exit from vertebral body (black arrow).

Assessment of screw location using CT scans has been shown to improve accuracy in comparison to plain radiographic assessments.<sup>38–40</sup> We found good correspondence between our interpretations on CT and anatomic dissections. Use of CT scans after surgery following placement of thoracic pedicle screws should be considered when there are concerns regarding lateral or anterior perforations.

While image guidance for placement of thoracic pedicle screws has been evaluated by other authors,<sup>8,29,31,41</sup> few comparisons of image guidance to standard fluoroscopic techniques have been performed. Assakar *et al*<sup>21</sup> found improved accuracy of thoracic pedicle screw placement using image guidance *versus* lateral view fluoroscopy. These authors did not use anteroposterior or axial pedicle fluoroscopic projections, nor did they perform foraminotomies to allow palpation of medial pedicle walls. Their comparisons are thus significantly different from our own.

In this study, use of image guidance did not increase accuracy of pedicle screw placement in the thoracic spine using the starting point described. Even after laminotomy, a large percentage of screws exited the pedicle;

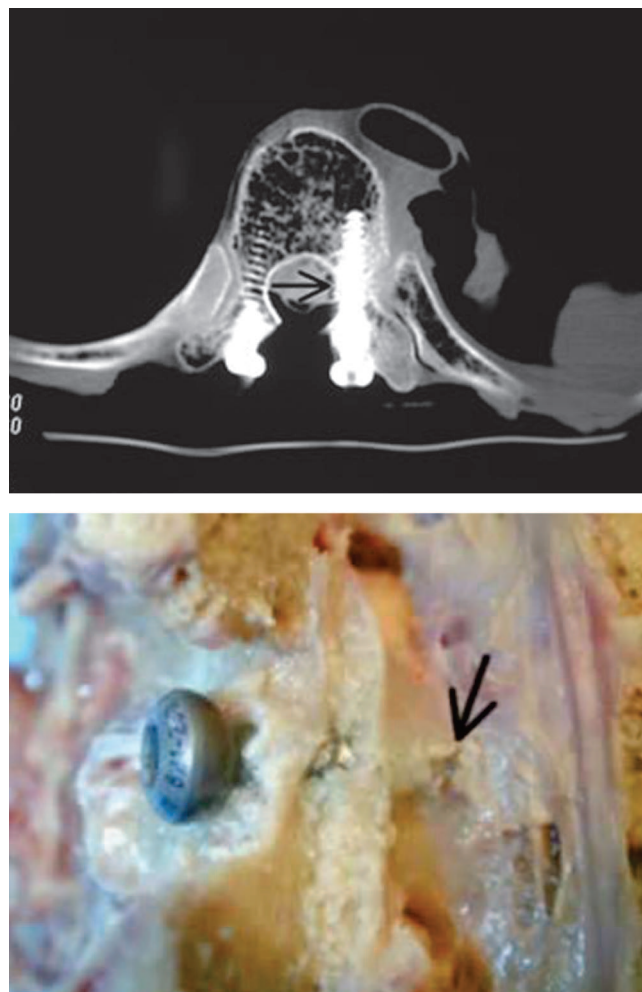


Figure 7. **A**, CT scan demonstrating possible medial protrusion of pedicle screw. **B**, Cadaveric dissection demonstrating visibility of screw threads but absence of significant perforation.

thus, this technique should be used only by experienced surgeons. Placement of pedicle screws using a lateral starting point and accepting lateral screw exit at the level of the rib head appears to offer a safe technique of pedicle screw placement in the thoracic spine.

#### ■ Key Points

- No significant medial intrusions occurred with the proposed starting point and insertion technique using fluoroscopic or stereotactic guidance.
- No significant difference in thoracic pedicle screw exit rate was noted between the stereotactic and fluoroscopically guided techniques.
- Postoperative CT scanning provides accurate assessment of titanium screws based on confirmations *via* anatomic dissection.

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# Giant Cell Tumor

## A Case Report of Recurrence During Pregnancy

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### Study Design. Descriptive.

**Objective.** To report a case of a recurrent giant cell tumor (GCT) of the lumbar spine during pregnancy.

**Summary of Background Data.** GCT is a locally aggressive tumor that primarily occurs in young female adults. These tumors rarely present in the spine, recur locally, and may be present during pregnancy because of growth promoting receptors.

**Methods.** A 31-year-old pregnant woman presented to us from Europe at 24 weeks' gestation (G1P1) with severe back pain and an enlarging mass. A large, firm, nontender mass was palpable in the right upper quadrant. Radiographs of the lumbar spine were obtained and revealed a 10-cm × 8 cm × 15 cm expansive bony mass at L2 with vertebral body collapse and junctional kyphosis. Following delivery of a healthy 6 lb. 8 oz. baby, MRI, CT, and full-length standing radiographs were obtained. A needle-guided biopsy showed amorphous bone with numerous giant cells consistent with a GCT. At 6 weeks postpartum, the tumor was resected.

**Results.** At 1-year follow-up, there is no evidence of local reoccurrence and the patient is without constitutional symptoms.

**Conclusion.** This is an unusual presentation of an expanding intra-abdominal mass originating from the lumbar spine during pregnancy. It most likely represents rapid growth of a previous unrecognized recurrence of a GCT. Close observation and follow-up CT scanning are imperative to identify and treat GCTs of the spine before rapid growth occurs.

**Key words:** pregnancy, abdominal tumor, giant cell.  
**Spine 2005;30:E332–E335**

### ■ Case Report

A 31-year-old gravita 1, para 1 woman presented to our institution at 24 weeks' gestation with complaints of intermittent severe back pain and right leg swelling. Phys-

ical examination demonstrated mild lumbar kyphosis and a large, firm, nontender mass in the right upper quadrant. She had no neurologic deficits or adenopathy. Medical and surgical history was significant for a "giant tumor" of the second lumbar vertebra diagnosed and treated in Russia in 1995.

Imaging studies were obtained, which included full-length radiographs (Figure 1), renal ultrasound, and magnetic resonance imaging (MRI). These studies demonstrated a 10 cm × 8 cm × 15 cm expansive bony mass centered at the second lumbar (L2) vertebral body with collapse and junctional kyphosis. Two large Steinmann pins were noted in a crossing pattern at L1 and L3.

Her obstetric evaluation revealed a healthy fetus and the decision was made to delay surgery until postpartum. After a vaginal term delivery with epidural anesthesia, repeat standing full-length radiographs, MRI of her abdomen with and without gadolinium, and CT scan of her spine, abdomen, and pelvis (Figures 1 and 2) were performed. These studies further revealed displacement of the liver, right kidney, and small intestine with inferior vena cava (IVC) compression. A CT-guided needle biopsy revealed amorphous bone with numerous giant cells (Figure 3).

Because of the paraspinal soft tissue expansion of this tumor, a multidisciplinary surgical approach was used to perform a marginal excision of the mass.

### Surgical Procedure

She underwent a staged anterior-posterior resection with subtotal spondylectomy of L1, and vertebrectomies of L2 and L3 through a right thoracoabdominal approach.

The liver was freed from the proximal tumor, followed by mobilization of the right ureter and kidney, which were closely adhered to the mass. The renal artery and vein were preserved, and vascularization of the kidney appeared adequate following resection. The IVC, iliac vein, and branching ilio-lumbar veins were then isolated, and the extruding mass was resected down to the IVC where the mass was noted to be densely adherent to the vessel wall. The consulting Vascular Surgery team determined that the IVC would best be managed by segmental resection; therefore, it was clamped, resected, and repaired with a 4-cm Teflon graft and the mass was freed.

The majority of the mass was excised by osteotomizing through the middle of the mass in a distal to proximal, and medial to lateral fashion, thus freeing it from the L2 vertebral body. Brisk bleeding was controlled by packing the vertebral body. After stabilization and hemostasis, she was transferred to the surgical intensive care unit.

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Acknowledgment date: June 23, 2004. First revision date: July 15, 2004. Acceptance date: October 12, 2004.

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No funds were received in support of this work. 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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Figure 1. Preoperative anteroposterior (A) and lateral (B) views demonstrating heavily calcified mass extending from L2.

Two days later, the patient returned to the operating room. Anterior exposure was obtained through the previous thoracoabdominal incision. The L1, L2, and L3 vertebral bodies were removed because of placement of the original instrumentation (Steinmann pin) in the L1 and L3 vertebral bodies, and a 90 mm × 22 mm titanium mesh cage was placed between the T12 and L4 vertebral

bodies and locked in place with a single rod screw construct (Figure 4).

After closure and placement of the patient in the prone position, the right L2 pars and remaining posterior elements were then osteotomized and the remaining tumor was removed. After the construct was stabilized with rods and bone graft, the patient was again recovered in the surgical intensive care unit. Neuromonitoring, including somatosensory, motor-evoked potentials and rectal monitoring, was performed and remained normal throughout the case.

## ■ Discussion

Lebert recorded the first case of microscopic observation of a bone tumor containing multinucleated giant cells in 1845.<sup>1</sup> Since this time, various clinical, radiologic, and histologic advances have been made regarding diagnosis and treatment of giant cell tumors (GCTs).

GCT of bone is relatively rare, accounting for only 10% of all primary bone neoplasms. Of these, only 5% to 10% of GCTs are found in the spine,<sup>2</sup> with the sacrum being the most common site of vertebral involvement.<sup>3,4</sup> More commonly, these tumors are found at the metaphysis and diaphysis of long bones, especially the distal femur, proximal tibia, and distal radius.<sup>5</sup> Characteristically, GCTs have a female predominance (1.5:1), with a peak incidence during the third and fourth decades.<sup>3,6,7</sup>

Microscopically, GCTs consist primarily of multinucleated giant cells and mononuclear stromal cells. Spindle cells, foamy macrophages, and reactive bone may also be seen.<sup>3</sup> In this case, pathologic evaluation revealed a constellation of patterns, *i.e.*, foci of GCT admixed with large areas of desmoplastic collagenous tissue for-

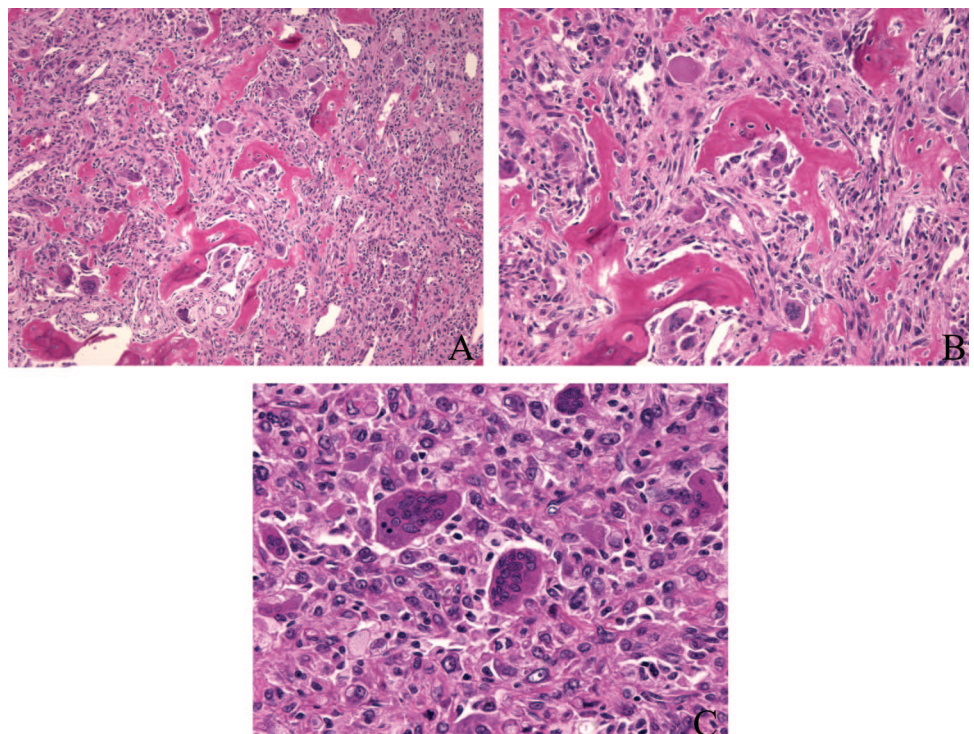


Figure 2. Histology of giant cell tumor: original magnifications: A, ×10; B, ×20; C, ×40. Giant cells are admixed with desmoplastic collagenous tissue and osteoid.





Figure 3. Preoperative lateral CT scan showing tumor at L2.

mation, focal active and slightly atypical fibrovascular proliferation, and lobulated mature fat with ossification.

Although GCTs are generally considered benign, they can be aggressive and locally invasive.<sup>1</sup> They have also been associated with malignant characteristics such as local recurrence and lung metastasis.<sup>3</sup> Histologic evaluation, however, is not predictive of outcome. Recurrence appears to be associated more with adjuvant radiation therapy and the extent of initial surgical excision. In a large series of axial GCTs, Althausen *et al* reported recurrence following surgical intralesional excision (27%), marginal excision (8%), and radical excision (0%).<sup>4</sup> Nonetheless, the extent of surgical excision is based on numerous factors, including tumor location and patient comorbidity. Various authorities also believe that radiation therapy, if considered, should be limited to 4,000 cGy and used only for incompletely resectable recurrent tumors.<sup>8,9</sup>

The two major concerns regarding radiation treatment are efficacy of the treatment and the frequency of sarcomatous transformation.<sup>10–13</sup> Multiple studies have demonstrated high local failure rates (7%–63%) for patients treated with radiation therapy.<sup>11,12</sup> Recent literature suggests that these studies were performed before the availability of modern imaging techniques and were based on patients treated with orthovoltage radiation, which is administered in low doses and multiple courses.<sup>10,11</sup> Total radiation dosage was therefore very high. Modern equipment and imaging techniques using a sin-

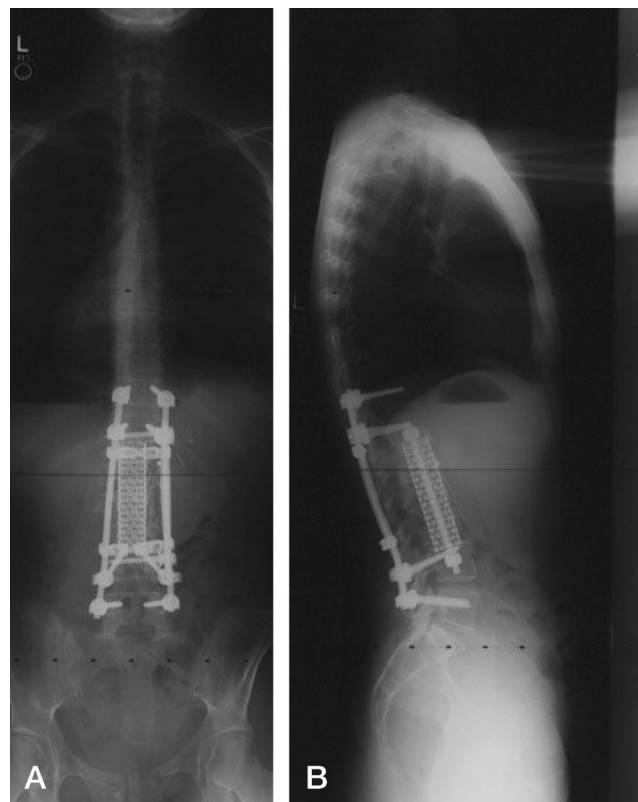


Figure 4. Preoperative anteroposterior (A) and lateral (B) views showing the removal of L1–L3 and subsequent placement of titanium mesh cage locked in place with single rod screw construct.

gle course of treatment with 50 or 60 Gy have shown a lower rate of local failure (15%),<sup>10,11</sup> and malignant transformation (0%–3%),<sup>10–12</sup> with long-term follow-up. Although surgical excision remains the treatment of choice, radiation therapy is recommended as an effective alternative for cases in which complete excision is not possible or morbidity is extreme.<sup>10–12</sup> The usefulness of adjuvant radiation therapy is currently being defined.<sup>13</sup>

GCTs occurring in pregnancy have been reported as early as the 1950s.<sup>14</sup> This was the first report suggesting a hormonal influence of tumor growth. However, conclusive scientific evidence is still lacking, although some authors have reported estrogen and progesterone receptors on some GCTs.<sup>5</sup> In this case, the tumor was negative for both estrogen and progesterone receptors. Other studies have focused on an immunologic explanation for GCT occurrence during pregnancy. Oncofetal antigens, which are similar to fetal antigens, have been found on a fibrosarcoma and an osteosarcoma cell line.<sup>5</sup> Nonetheless, no study has demonstrated expression of similar oncofetal antigens on GCTs. Finally, this association may be purely coincidental, due to the frequency of this tumor in women of childbearing age.<sup>5</sup>

Our patient was young and otherwise healthy. Relatively little was known about the previous treatment of her “giant tumor” with regards to the exact diagnosis and extent of excision. Most likely, complete surgical excision was not obtained. Using a multidisciplinary ap-

proach, fetal and maternal health was monitored before resection. Because the natural history of GCT is normally one of slow growth, termination of pregnancy is not indicated, as is the case for rapidly growing sarcomas.<sup>7</sup> In this situation, the patient did not demonstrate neurologic impairment or fetal distress secondary to the mass. If there were significant vertebral body collapse with a polyradiculopathy or cauda equina syndrome, then surgical intervention may have been required. Because of the significant blood loss expected from surgical excision, equal to or exceeding total circulating blood volume, significant fetal distress or harm would be expected, and caesarean delivery would be required. There is no known guidance in the literature in this situation; fortunately, this did not occur. In this case, the patient refused adjuvant radiation therapy following resection. She remains tumor free at her 2-year follow-up. Continued close postoperative monitoring with computed tomography scanning is needed to detect early recurrence of GCT of the spine.

#### ■ Key Points

- Giant cell tumors consist primarily of multinucleated giant cells and mononuclear stromal cells. They are more commonly found at the metaphysis and diaphysis of long bones.
- Observation and follow-up CT scanning are imperative to identify and treat giant cell tumors of the spine before rapid growth occurs.
- Giant cell tumors have a female predominance (1.5:1), with a peak incidence during the third and fourth decades.

- Giant cell tumors rarely present in the spine, recur locally, and may be present during pregnancy because of growth promoting receptors.

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## Bone Lymphangiomatosis: Treatment With Percutaneous Cementoplasty

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**Study Design.** Case report, minimally invasive technique.

**Objectives.** Disseminated lymphangiomatosis is a rare disorder that can produce clinical manifestation secondary to soft tissue, visceral and bone involvement. The overall prognosis of this disorder is usually poor, and the current treatment options for its sequelae are limited and only palliative. In this report, we present the use of cementoplasty in the percutaneous treatment of a sacral lymphangiomatous bone lesion producing severe pain.

**Summary of Background Data.** Disseminated lymphangiomatosis is a rare disorder that can produce clinical manifestation secondary to soft tissue, visceral, and bone involvement. Major morbidity related to skeletal involvement requiring surgical intervention is less common than that related to visceral involvement, but it has been reported in a few case reports to palliate neurologic sequelae secondary to vertebral involvement. We present case of osteoplasty used to treat a painful osteolytic sacral lesion in a patient with diffuse lymphangiomatosis. Computed tomography guided osteoplasty injecting acrylic bone cement into the lesion resulted in almost immediate reduction in pain.

**Methods.** The technique and results of minimally invasive percutaneous computed tomography-guided cementoplasty of a painful osteolytic sacral lesion resulting from chylous reflux in a patient with lymphangiomatosis is presented.

**Results.** Computed tomography was used to accurately position a 13-gauge needle into a dominant sacral osteolytic lesion. The injection of bone cement into the sacral lesion was then monitored by intermittent CT imaging. The patient reported substantial pain relief within several hours of the procedure.

**Conclusion.** The case presented demonstrates the feasibility and efficacy of computed tomography-guided cementoplasty used to palliate unusual causes of benign osteolytic bone lesions. These procedures can be performed as outpatients with minimal recovery.

**Key words:** lymphangiomatosis, bone cement, osteoplasty, vertebroplasty. *Spine* 2005;30:E336–E339

phatic system affecting the soft tissues, viscera, and skeletal system. The clinical manifestations depend on the site(s) of involvement,<sup>1</sup> and the respiratory system is often the site involved at the time of diagnosis.<sup>2</sup> Bone involvement may cause pain and swelling, which may be predominant, especially in the presence of a pathologic fracture. The overall prognosis of this disorder is usually poor, and the current treatment options for its sequelae are limited and only palliative.<sup>1,2</sup> In this report, we present the use of osteoplasty in the percutaneous treatment of a sacral lymphangiomatous bone lesion producing severe pain.

### ■ Case Report

A 21-year-old man was initially evaluated for lymphedema and recurrent cellulitis of his scrotum and lower right leg. A mass in his suprapubic region was identified, sampled on biopsy, and found to be a lymphangioma. At age 23, he underwent surgical debulking of the lymphangioma in the right groin and scrotal area and plastics reconstruction that included a rectus myocutaneous flap and a lympho-lymphatic shunt with vein graft from the right groin to the left. He continued to have chronic drainage from his right buttock and scrotum and recurrent episodes of cellulitis. At age 29, he began experiencing shortness of breath and was found to have a chylous right pleural effusion that was treated by insertion of a pleuroperitoneal shunt, followed by pleurectomy and talc pleurodesis. He subsequently developed *Staphylococcal empyema* and was treated with vancomycin.

At age 31, he underwent a second debulking operation with plastic reconstruction to treat the chronic recurrent drainage from his right buttock and scrotum. Approximately 1 month later, he began experiencing severe pain in his right hip and low back that eventually reached a pain score of 4 of a maximum of 5. Computed tomography (CT) and magnetic resonance imaging of his pelvis demonstrated diffuse lymphangiomatous involvement of the bone and soft tissues (Figure 1). A predominant, lytic lesion involving the right sacrum and ilium was identified and believed to be the source of pain. Biopsy of the right sacral lesion was performed and yielded a milky fluid that contained a polyclonal B-cell population on flow cytometry.

Interventional Radiology was then consulted about percutaneous options for treating the lytic sacral lesion as a means of alleviating the patient's pain. Our initial discussions included sclerotherapy with ethanol and osteoplasty.

Disseminated lymphangiomatosis is a rare congenital entity that is characterized by malformation of the lym-

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Acknowledgment date: June 7, 2004. First revision date: October 11, 2004. Acceptance date: October 12, 2004.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. 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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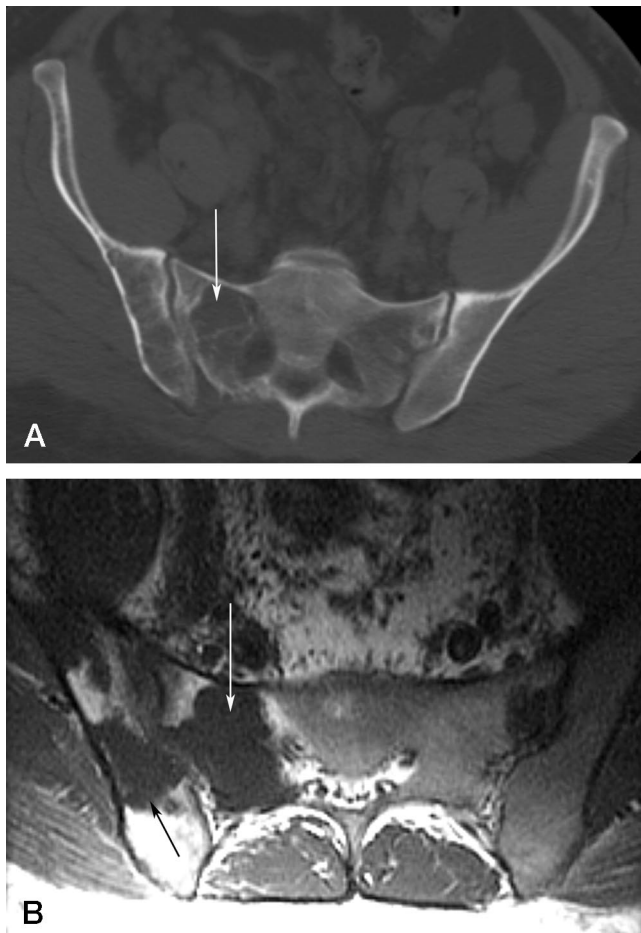


Figure 1. Computed tomographic (A) and (B) magnetic resonance imaging of the patient's sacrum prior to intervention demonstrate predominant lytic lesions within the sacrum (white arrows) and right ilium (black arrow).

Before deciding which treatment option to pursue, we first inserted a 13-gauge vertebroplasty needle into the predominant right sacral lesion under computed tomographic (CT) guidance with the patient prone. A white, milky fluid, consistent with the appearance of chyle, was easily aspirated from the lesion. Approximately 10 mL of dilute (30%) contrast medium (Optiray 320, Mallinckrodt Inc., St. Louis, MO) was instilled into the lesion. CT through this region (Figure 2A) was performed, enabling us to identify extraosseous dissemination of the contrast medium (Figure 2B). Because of this finding, we thought that ethanol sclerosis could not be controlled sufficiently and thus could result in unwanted complications. We therefore chose the alternative option of osteoplasty because the cement materials used in that procedure are more viscous than ethanol, and we thought it could be better controlled.

We then injected approximately 7 mL of bone cement (Parallax Medical Inc., Scott Valley, CA) under direct CT fluoroscopic monitoring. Follow-up CT imaging through the region of interest (Figure 3) demonstrated good distribution of the cement throughout the lesion without obvious extraosseous leakage. Within 1 hour

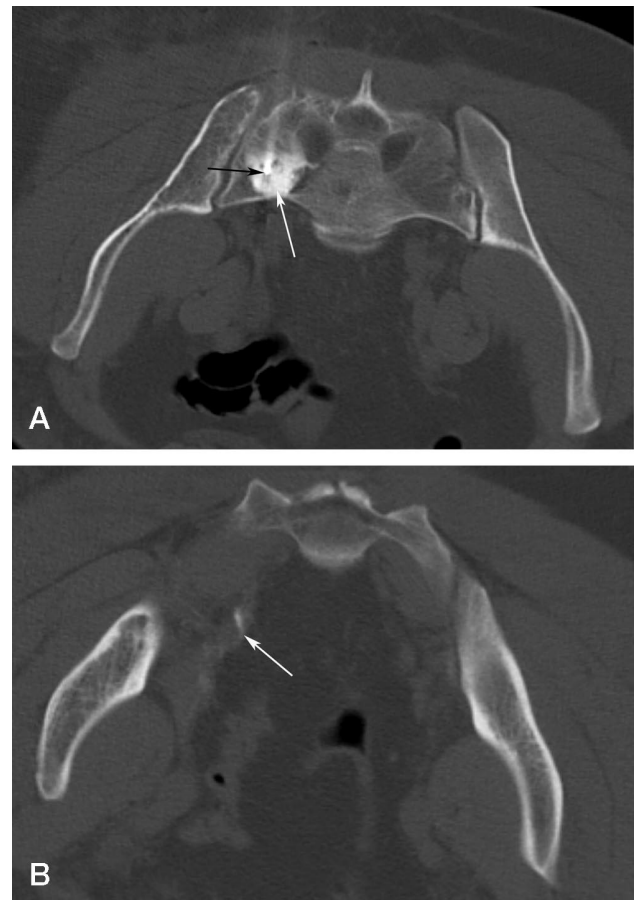


Figure 2. Computed tomographic images of the sacrum (A) and the pelvis (B) obtained after injection of contrast medium into the sacral lytic lesion. Note the presence of contrast within the lesion and also note the presence of contrast medium extravasation in the pelvic soft tissues (white arrows). The tip of the needle (black arrow) used for osteoplasty is situated within the center of the lytic lesion (A).

after completion of the procedure, the patient reported a reduction in pain and, at 1-week follow-up, had a pain score of only 1 of 5. Four months after the procedure, the patient was experiencing no pain in his right hip or low

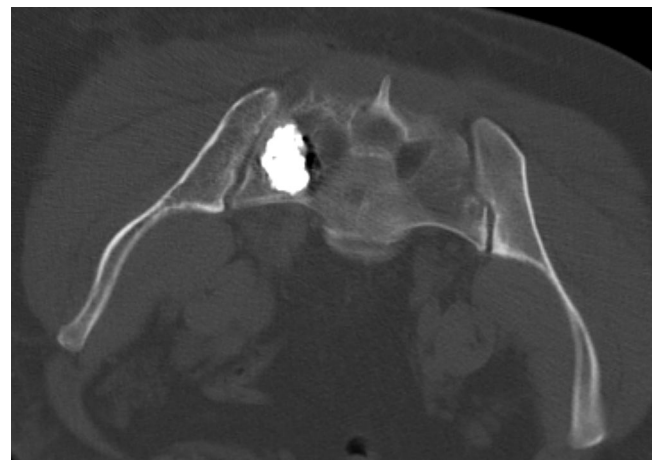


Figure 3. Computed tomographic image of the patient's sacrum after injection of the acrylic cement.



back pain and was able to perform his daily activities normally.

## ■ Discussion

The lesions in cases of disseminated lymphangiomatosis are usually diffuse or multifocal and result from the proliferation of complex, irregular lymphatic channels. In most situations, multiple skeletal lesions are present and often associated with soft tissue and visceral involvement. Usually, the major morbidity and mortality associated with this disease are secondary to visceral involvement, which can lead to chylothorax, chylopericardium, hepatosplenomegaly, and other similar clinical events. Chyle obtained from the sacral lesion implies the presence of chylous reflux secondary to lymphatic obstruction from the intestinal lymphatics into the skeletal lymphatics and subsequently into bone. The presence of chylothorax is a poor prognostic indicator.<sup>3</sup> In our patient, standard palliative maneuvers were used to treat both the sequelae of extensive soft tissue lymphangiomatosis and chylothorax.

Although the bone involvement in our patient was first documented 4 years before our intervention, his bone pain occurred only within 2 months of the osteoplasty and was perhaps secondary to an occult fracture or to recent growth of the lytic lesion. Despite the presence of diffuse bony involvement, we considered the dominant lesion within the sacrum to be the source of the pain on the basis of our clinical assessment. Major morbidity related to skeletal involvement requiring surgical intervention is less common than that related to visceral involvement, but it has been reported.<sup>4,5</sup> Reports by Jea *et al*<sup>4</sup> and Watkins *et al*<sup>5</sup> described the use of spinal decompression at the craniocervical and cervicothoracic junctions to palliate neurologic sequelae secondary to vertebral lymphangiomatosis.

Initial discussions regarding minimally invasive therapies included the use of ethanol for sclerosis of the lesion within the sacrum. The principle behind this approach is similar to that used in the treatment of congenital venous malformations.<sup>6–8</sup> Ethanol sclerosis involves the insertion of a needle into the mass of malformed venous channels and injection of ethanol, which then produces endothelial cell damage and subsequent thrombosis. Because ethanol is caustic, care must be taken to prevent its flow into the native venous system or extravasation into the surrounding structures, where it can cause skin and soft tissue necrosis. For this reason, we chose to inject dilute contrast medium into the lesion as a means of simulating the injection of ethanol and assessing the potential for its extraosseous extravasation before we undertook the therapeutic intervention. The contrast medium was identified outside the bone in the region of the sciatic notch. Thus, an alternative agent was chosen. Acrylic cement is a more viscous agent than ethanol, and we thought it would be less likely to leak into the adjacent soft tissues. Other re-

cent case reports have described the successful use of such osteoplasty for palliating metastatic foci within the pelvis.<sup>9,10</sup>

Percutaneous osteoplasty is a procedure in which acrylic surgical cement polymethylmethacrylate is injected into bone for pain relief and bone stabilization. An alternative term used to describe this technique is vertebroplasty, which specifically indicates injection of the cement into a vertebral body of the spine. The first report of percutaneous vertebroplasty was published in 1987,<sup>11</sup> and since then the technique has gained popularity as an effective treatment for osteoporotic vertebral body compression fractures. When percutaneous vertebroplasty is performed for osteoporosis, its success is defined as achievement of clinically significant pain relief and/or improved mobility, as measured by validated assessment tools and is reported in excess of 90%.<sup>12,13</sup> Kyphoplasty is an alternative but similar technique to vertebroplasty that involves the deposition of bone cement in a more controlled fashion to restore vertebral body height and stabilize the bone.<sup>14</sup>

Vertebroplasty and kyphoplasty have also been used effectively for patients with myeloma and osteolytic spinal metastasis.<sup>15–20</sup> Weill *et al*<sup>19</sup> reported their results with vertebroplasty in 37 patients (52 levels) with spinal metastasis. Twenty-four (73%) performed for pain relief resulted in clear improvement. One major complication secondary to cement extrusion into the neural foramen required surgical intervention. Cotten *et al*<sup>21</sup> reported their prospective results with vertebroplasty in 37 patients with oncologic vertebral compression fractures (spine metastases, *n* = 29; myeloma, *n* = 8). Partial or complete pain relief was observed in 97%. Cement extravasation requiring surgical decompression occurred in 2 patients. Cohen *et al*<sup>20</sup> recently reported their 10-year experience with vertebroplasty. Of the 148 patients treated 31 patients (43 levels) had compression fractures secondary to malignant vertebral tumors. Functional improvement (reduction in analgesic requirements) occurred in 58% as compared to 87% for those with osteoporotic compression fractures. In one of the larger series reported by Lieberman and Reinhardt,<sup>17</sup> 52 patients with myeloma and 11 patients with metastases were treated with kyphoplasty for painful osteolytic vertebral collapse. In the myeloma group, statistically significant improvement between pretreatment and post-treatment Short Form 36 Health Survey scores (SF-36) for bodily pain and physical function was achieved. Additionally, there was significant improvement in the visual analog pain scale score and the Oswestry Disability Index score.

We used osteoplasty successfully in our patient in whom it resulted in almost immediate reduction in pain. Thus, we think this technique can potentially be used for other sites of bone involvement in patients with this rare congenital disorder, disseminated lymphangiomatosis.

### ■ Key Points

- Vertebroplasty and kyphoplasty are effective tools for oncologic causes of vertebral compression fractures.
- Percutaneous bone cement injection can be used to manage pain-related symptoms from lytic bone abnormalities associated with lymphangiomatosis.
- Imaging guidance is essential for accurate needle placement and monitoring cement deposition.

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## Intracranial Hypotension Induced by Cervical Spine Chiropractic Manipulation

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Min-Kyu Park, MD,† Kun-Woo Park, MD,† Joon-Shik Yoon, MD,‡ and Dae-Hie Lee, MD,†

### Study Design. Case report.

**Objectives.** We report a case of intracranial hypotension ensuing after a spinal chiropractic manipulation leading to cerebrospinal fluid (CSF) isodense effusion in the upper cervical and thoracic spine.

**Summary of Background Data.** The etiology of intracranial hypotension is not fully understood, but CSF leakage from spinal meningeal diverticula or dural tears may be involved.

**Methods.** A 36-year-old woman presented with neck and both shoulder pain 4 days earlier. She undertook a spinal chiropractic manipulation. After this maneuver, she complained of a throbbing headache with nausea and vomiting. Her headache worsened, and lying down gave the only measure of limited relief. In CSF study, it showed dry tapping. Brain MRI showed pachymeningeal gadolinium enhancement. Thoracic spine MRI showed CSF leakage. After admission to the hospital, she was treated by hydration and pain control over several days. However, her headache did not improve.

**Results.** She was treated by epidural blood patch. Afterwards, her headache was improved. This is the first case of spontaneous intracranial hypotension in which spinal chiropractic manipulation coincided with the development of symptoms and in which a CSF collection in the upper cervical and thoracic spine was demonstrated radiographically in Korea.

**Conclusions.** From this case, we can understand the etiology of intracranial hypotension and consider the complication of chiropractic manipulation.

**Key words:** intracranial hypotension, chiropractic manipulation, epidural blood patch. **Spine 2005;30:E340–E342**

tively. One Canadian study showed that approximately 134.5 million cervical manipulations were performed by chiropractors in Canada during 10 years.<sup>3</sup> There has also been an increasing utilization of manual manipulation by the medical physicians and physical therapists around the world.<sup>4</sup> The growing recognition of cervical manipulation, including chiropractic manipulation as a treatment for neck pain and cervicogenic headaches, has led to an increased scrutiny for the potential complications that may result from this treatment approach. However, the complications relative to the increasing utility of cervical manipulation have rarely been reported.

We report here on a patient whose clinical and radiographic findings were consistent with intracranial hypotension, and the patient had a recent history of cervical spine chiropractic manipulation.

### ■ Case Report

A 37-year-old woman visited our hospital and presented with a 4-day history of headache radiating to the occiput and posterior nuchal area. She had no history of meningitis, lumbar puncture, or head trauma. She had received a chiropractic maneuver 5 days previously because of her chronic neck and shoulder pain. The practitioner had grasped her head in supine position and rotated her head while exerting axial tension on her neck. During the maneuver, she felt sharp pain on her posterior neck and upper thoracic spine, and then her headache developed. Her headache was intensified in an erect position and was somewhat relieved when she was in a supine position. This headache pain was also associated with nausea and vomiting. Her neurologic examination was normal and her brain CT showed diffuse meningeal enhancement. A subsequent lumbar puncture demonstrated a depressed opening cerebrospinal fluid (CSF) pressure of 40 mm H<sub>2</sub>O. The extensive CSF analysis revealed no abnormal findings. Magnetic resonance imaging (MRI) of brain revealed diffuse continuous smooth pachymeningeal enhancement (Figure 1). The MRI of thoracic and lumbar spine showed abnormal epidural and subdural fluid collections, spinal epidural venous engorgement, and diffuse spinal dural enhancement (Figures 2 and 3). The imaging findings of the brain and spine were compatible with manifestation of a CSF hypovolemia or a low CSF pressure. Laboratory testing revealed no evidence of connective tissue disease. Such conservative management as bed rest, intravenous fluid hydration, and analgesics did not improve her headache. The patient underwent a 20-mL epidural blood patch at C7–T2 and at last follow-up her postural headache was completely relieved.

Ever since a multidisciplinary consensus was reached about the effectiveness of manipulative therapy, the popularity and utilization of cervical manipulative therapy have been growing every year.<sup>1</sup> Hurwitz *et al*<sup>2</sup> conducted a study by retrospectively reviewing the medical records from randomly selected chiropractic offices, from 1985 through 1991, and they found that the chiropractic visit rates in the United States and Ontario are estimated to be 101.2 and 140.9 visits per 100 person-years, respec-

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Acknowledgment date: September 7, 2004. Acceptance date: September 29, 2004.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. 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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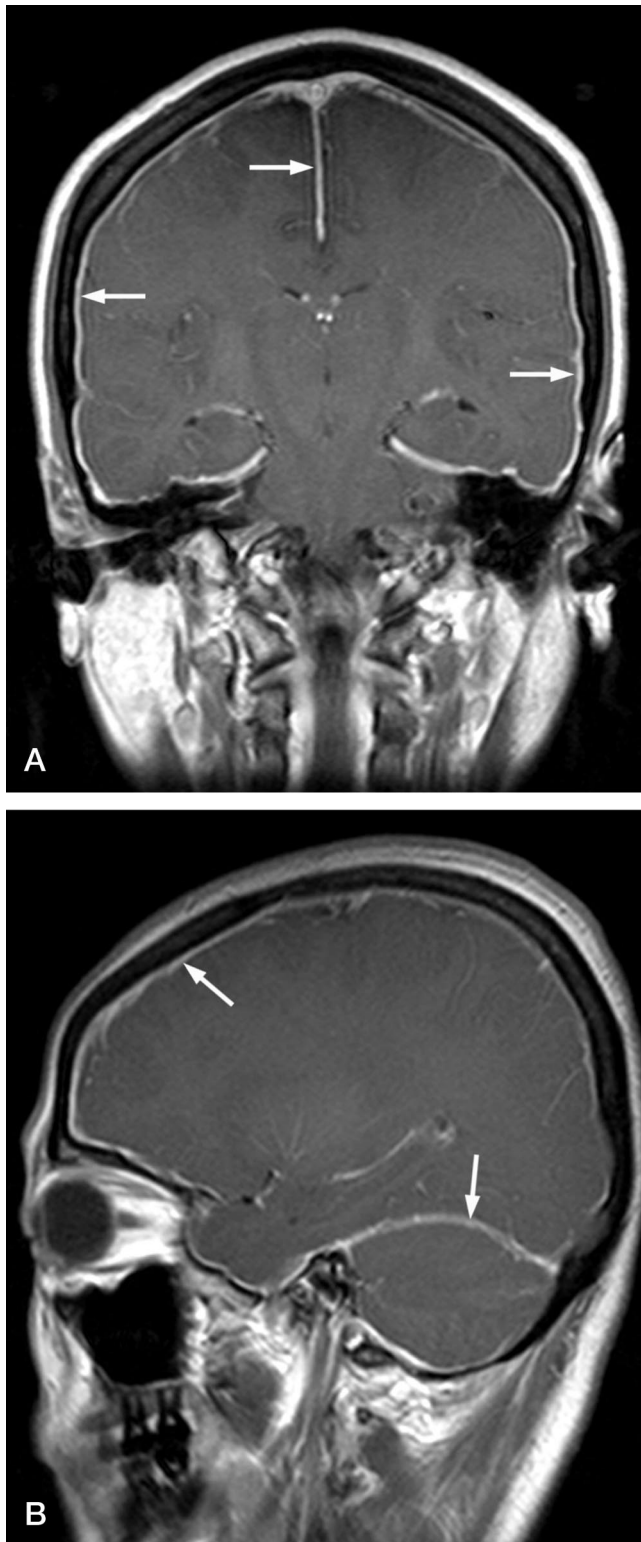


Figure 1. Contrast-enhanced coronal (A) and sagittal (B) MR images of the brain show diffuse pachymeningeal enhancement (arrows).

## Discussion

The major complications resulting from chiropractic maneuvers are stroke accompanied by arterial dissection, phrenic nerve injury, and myelopathy.<sup>5-7</sup> These major complications are rare, but they can be life-threatening.



Figure 2. A, Fat-saturated sagittal T2-weighted MR image of the thoracic spine shows epidural (asterisks) and subdural (sd) fluid collection. B, Sagittal gradient-echo MR image of the thoracic spine reveals no evidence of hemorrhagic dark signal intensity in the epidural and subdural fluid collection. C, Contrast-enhanced fat-suppressed sagittal MR image of the thoracic spine demonstrates diffuse dural enhancement (arrow) and epidural venous engorgement (arrowhead). D, Contrast-enhanced fat-suppressed sagittal MR image of the lumbar spine discloses diffuse dural enhancement with dilated epidural venous plexus (asterisks).

Minor side effects such as stiffness, radiating pain, dizziness, and nausea are common, but intracranial hypotension after chiropractic maneuvers has rarely been reported. In a study about the clinical characteristics of intracranial hypotension, 23.3% (7 of 30) of patients had a previous history of trauma. In this study, 1 of these patients had a history of spine chiropractic manipulation.<sup>8</sup> Beck *et al*<sup>9</sup> have recently reported on a woman



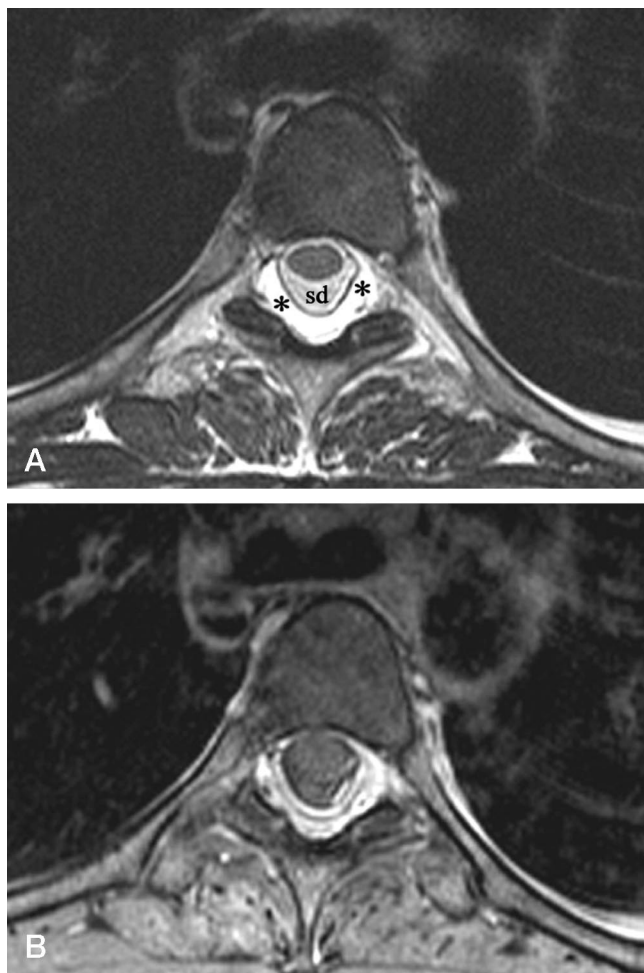


Figure 3. **A**, Axial T2-weighted MR image at the level of the seventh thoracic spine shows epidural (asterisks) and subdural fluid collection (sd). **B**, Contrast-enhanced fat-saturated axial T1-weighted MR image at the same level reveals diffuse enhancement in the spinal canal due to dural enhancement and engorged venous plexus.

who had postural headache and incomplete right abduction palsy after chiropractic manipulation. Although the MRI revealed CSF fluid accumulation in the paravertebral soft tissue and musculature, the patient was diagnosed as having infection, and she was given antibiotics and even an antituberculosis regimen of drugs. After the final diagnosis arrived at intracranial hypotension, the patient was discharged from the hospital and her symptoms were noted to have resolved spontaneously.

Intracranial hypotension is an uncommon condition characterized by a low CSF pressure and postural headache. Spontaneous intracranial hypotension was first described by Schaltenbrand in 1938, and it was thought to be a rare condition.<sup>10</sup> Intracranial hypotension is now being recognized with increasing frequency by the advent of MRI. Most cases of intracranial hypotension result from spontaneous CSF leaks, and such leaks may result from a lumbar puncture, myelography, spinal anesthesia, or craniospinal surgery.<sup>11</sup> The exact cause of a spontaneous CSF leak is rarely established, but two factors may contribute the CSF leaks; one is trauma and another is a weakness of the dural sac.<sup>12</sup> The minor trauma such

as coughing, physical activities, and pushing may contribute to the onset of CSF leaks. The theory regarding the focal weakness of dural sac as the predisposing factor of spontaneous intracranial hypotension is supported by literature reporting on the meningeal defects observed for Marfan syndrome or other connective tissue diseases.<sup>13–15</sup> It is possible that in some patients a combination of both factors, a weakened thecal sac and a relatively trivial trauma, may lead to CSF leaks.

Although intracranial hypotension has been rarely reported, physicians should be aware of possible complications when patients have a history of manipulative therapy and they present with abrupt postural headache, and this awareness by the physician will help to avoid additional costly and unnecessary testing.

### ■ Key Points

- Intracranial hypotension is an uncommon condition characterized by a low CSF pressure and postural headache.
- Intracranial hypotension could be complicated by chiropractic manipulation.
- Physicians need to be aware of the possibility of intracranial hypotension when patients have a history of manipulative therapy and they present with abrupt postural headache.

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# Transient Paraparesis After Laminectomy for Thoracic Myelopathy due to Ossification of the Posterior Longitudinal Ligament

## A Case Report

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### Study Design.

Case report.

**Objectives.** We report a case with thoracic myelopathy due to ossification of the posterior longitudinal ligament (OPLL) of the spine, in which neurologic deterioration progressed after laminectomy and was markedly reversed after additional posterior instrumented fusion.

**Summary of Background Data.** Many different surgical procedures may be used in the treatment of thoracic OPLL. However, the possibility of postoperative paraplegia remains a major risk, and consistent protocols and procedures for surgical correction of thoracic OPLL have not been established.

**Methods.** The patient was a 53-year-old man with continuous OPLL at T3–T8 that compressed the spinal cord anteriorly. Anterior decompression surgery employing a posterior approach was initiated, but during OPLL extirpation electrophysiologic monitoring of spinal cord activity showed abnormalities. As a result, the procedure was converted to a wide laminectomy. Over the next 4 weeks, kyphosis of the thoracic spine increased and myelopathy worsened, producing severe paraparesis.

**Results.** Four weeks after surgery, posterior instrumented fusion (T1–L1) was performed without correction of the kyphosis. After the fusion, neurologic deficits gradually recovered and the patient was fully recovered after 10 months. At follow-up 15 years after the fusion, no neurologic deterioration was seen despite the presence of residual anterior impingement of spinal cord by OPLL.

**Conclusions.** The present case suggests that kyphosis and instability are major factors that affect the severity of thoracic myelopathy due to OPLL, and posterior fusion with spinal instrumentation is a safe and effective adjunct procedure for surgical treatment of thoracic OPLL.

**Key words:** ossification of spinal ligament, posterior longitudinal ligament, thoracic myelopathy, paraparesis, laminectomy. *Spine* 2005;30:E343–E346

cervical OPLL.<sup>1,2</sup> Several factors increase the difficulty of surgery for thoracic OPLL: 1) the thoracic spine is naturally kyphotic, and decompressive laminectomy is less effective since the backward shift of the spinal cord is restricted; 2) the spinal cord at the site of compression is more vulnerable to damage because of its relative avascularity; and 3) the surgical approach from the anterior plane is restricted because of the presence of the thoracic ribcage.

To date, many surgeons have performed a variety of surgical procedures to correct thoracic OPLL.<sup>1–6</sup> However, the possibility of postoperative paraplegia remains a risk, and consistent protocols for specific procedures for surgical treatment of thoracic OPLL have not been established.

In this article, we report a case of thoracic myelopathy due to OPLL, in which paraparesis occurred after laminectomy, and it was markedly reversed by an additional posterior instrumented fusion. This report provides us with some clues for clarifying the mechanisms of postoperative neurologic deterioration in thoracic OPLL and developing an appropriate surgical protocol for treatment of this disorder.

### ■ Case Reports

A 53-year-old man with a 5-month history of gait disturbance was admitted to the Chiba University Hospital in August 1988. His gait was spastic, and he needed assistance on stairs. Muscle strength was within normal limits in the lower limbs, but he had distal dominant sensory loss below the umbilicus, showing a Grade 5/10 hypalgesia at feet. Hyperreflexia was present at bilateral patellar and Achilles tendons, and ankle clonus was transiently positive bilaterally. Babinski sign was negative. His bladder function was slightly disturbed, and micturition was frequent. Radiologic examination revealed a continuous OPLL at thoracic spine from T3 to T8. Kyphosis at T3–T8 was 14° (Figure 1). An ascending myelogram showed subtotal block at T5 and anterior indentation at T8 (Figure 2). CT myelogram revealed OPLL compressing the spinal cord anteriorly (Figure 1).

The patient was prepared for surgical treatment, initially planned as an anterior decompression using a posterior approach with electrophysiologic monitoring of spinal cord activity. At first, laminectomy from T3 to T8 was performed uneventfully. On drilling down the

Clinical results of surgical treatment of ossification of the posterior longitudinal ligament (OPLL) of the thoracic spine have been unfavorable compared with those for

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Acknowledgment date: September 23, 2004. Acceptance date: October 4, 2004.

The manuscript submitted does not contain information about medical device(s)/drug(s).

No funds were received in support of this work. 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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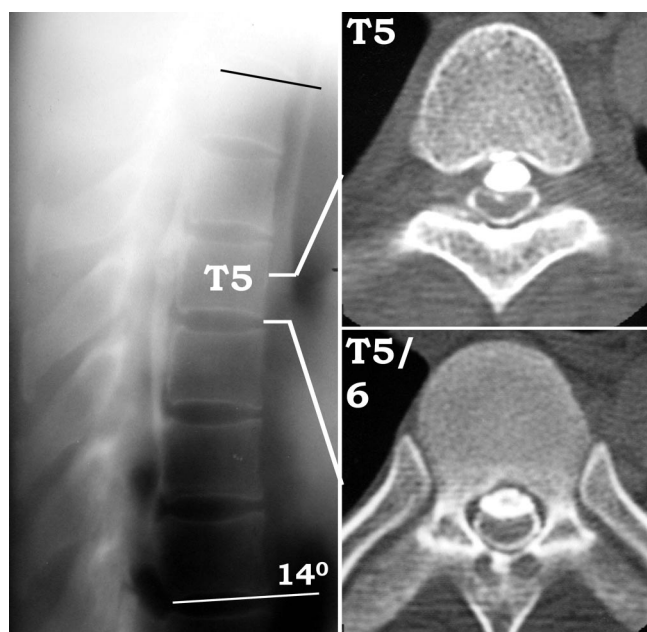


Figure 1. Preoperative radiographic images obtained in a 53-year-old man with thoracic myelopathy. A midsagittal tomogram at thoracic spine (left) shows a continuous type ossification of the posterior longitudinal ligament (OPLL) from T3 to T8. Thoracic kyphosis at T3–T8 is 14°. Axial views of computed tomography (CT) myelogram at T5 (right, upper) and T5–T6 (right, lower) indicate OPLL compressing the spinal cord anteriorly.

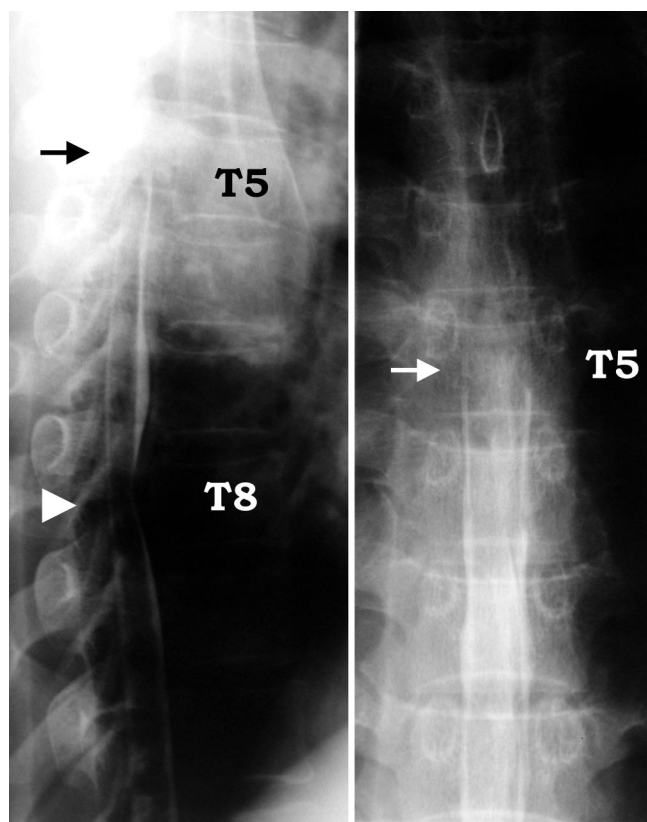


Figure 2. A lateral view (left) and an anteroposterior view (right) of ascending myelogram show subtotal block at T5 (arrows) and anterior indentation at T8 (arrowhead).

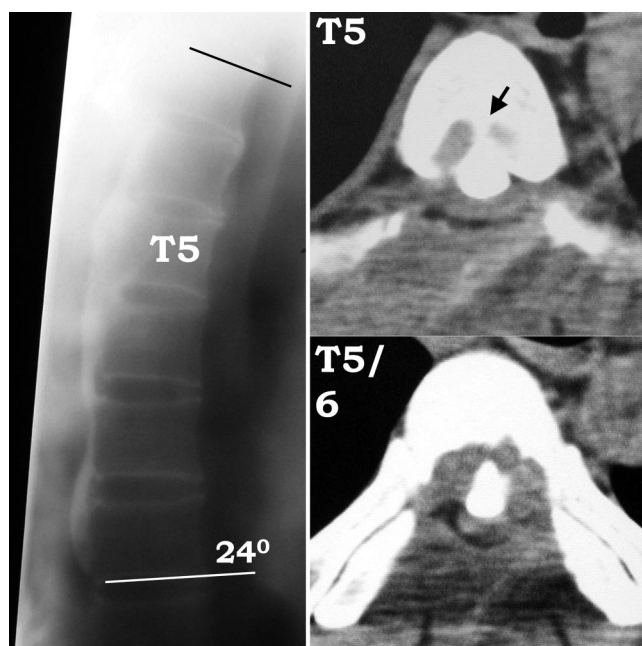


Figure 3. Radiographic images obtained 3 weeks after the first surgery. A midsagittal tomogram (left) shows increased thoracic kyphosis at T3–T8, measuring 24°. Axial CT images at T5 (right, upper) and T5–T6 (right, lower) indicate that the extirpation of OPLL is completed at T5–T6 but incomplete at T5 (arrow).

pedicles and initiation of extirpation of the OPLL from the posterolateral direction, the spinal cord-evoked potential showed increased latency and decreased amplitude. Conservative criteria indicated that the potential for damage to the spinal cord was too high to continue the planned procedure. Thus, the OPLL extirpation was not completed, and some anterior cord compression by OPLL remained. Free fat was grafted over the dura, and the incision was closed.

After surgery, the patient awoke with no neurologic deficit. At 2 days after surgery, however, he reported paresthesia in both legs. At 7 days after surgery, both motor and sensory loss appeared, showing a Grade 4/5 muscle strength and a Grade 3/10 hypalgesia at both lower limbs. The neurologic deterioration progressed, and severe paraparesis was evident 4 weeks after surgery (Grade 1/5 muscle strength and Grade 1/10 hypalgesia at both lower limbs). In addition, sustained ankle clonus and Babinski sign appeared bilaterally. Bladder function was severely disturbed with complete urinary retention. Postoperative radiographs demonstrated increased thoracic kyphosis at T3–T8, measuring 24° (Figure 3). CT showed that the extirpation of OPLL was incomplete at T5 (Figure 3, arrow).

Four weeks after the first surgery, the patient underwent an additional staged surgery, planned as an instrumented fusion posteriorly followed by a corpectomy and anterior decompression through thoracotomy. During the second surgery, we reopened the wound and removed the free fat originally placed over the dura. There were no findings of epidural hematoma or other tissues that compressed the spinal cord posteriorly. We then



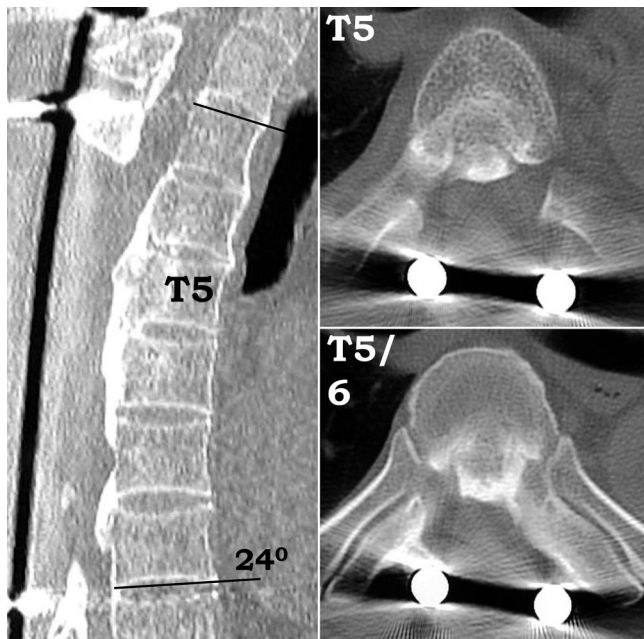


Figure 4. Radiographic images obtained 15 years after the second surgery. A midsagittal reconstruction of CT (left) shows no evidence of the progression of residual OPLL. Thoracic kyphosis at T3–T8 remains 24°. Axial CT images at T5 (right, upper) and T5–T6 (right, lower) show the residual OPLL.

performed a posterior instrumented fusion at T1–L1. For instrumenting, T1 facet hooks, T10 transverse process hooks, and L1 lamina hooks were placed bilaterally, and rods were placed without correction of the kyphosis. We evaluated the spinal cord with intraoperative ultrasonography and found that subarachnoid space was present at the dorsal side of spinal cord at T5, but not at its anterior side, where spinal cord was compressed by OPLL anteriorly. The incision was closed, and anterior decompression surgery was planned for about 3 weeks later.

Immediately after the instrumented fusion, no neurologic recovery was seen. Three days after the fusion, however, the patient presented with a decrease in lower limb spasticity bilaterally. Two weeks after surgery, motor and sensory deficits began to recover, showing a Grade 2/5 muscle strength and a Grade 3–4/10 hypalgesia bilaterally. Bladder function also recovered and micturition became possible. Since the neurologic recovery steadily progressed after the instrumented fusion, we suspended the planned anterior decompression surgery.

Six weeks after the instrumented fusion, the patient's muscle strength increased to a Grade 4/5. He could stand up with assistance at 2 months postfusion and walk with aid of a cane at 3 months. Seven months after the fusion, he could walk without cane. At 10 months, he was free from neurologic deficits and returned to work. At the final follow-up 15 years after fusion, the patient could run, and no neurologic deterioration was seen. Radiographs showed that thoracic kyphosis at T3–T8 remained at 24°, but no evidence of the progression of residual OPLL was seen (Figure 4).

## Discussion

When we planned the surgical procedure for the present case in 1988, there were several reports describing the clinical results of different surgical procedures for thoracic myelopathy due to OPLL.<sup>1,2</sup> In their reports, neurologic recovery after anterior decompression procedures was generally better than that after posterior decompression procedures. As for the anterior decompression for thoracic OPLL, anterior decompression and fusion (ABF) through thoracotomy was a standard method and was reported by several authors.<sup>1,2</sup> However, the indication of ABF was limited for localized OPLL; the number of spinal segments to be decompressed was generally limited to three or four. In addition, after ABF for thoracic OPLL, the possibility of leakage of cerebrospinal fluid into the intrathoracic space remained a negative factor. Once this complication occurs, it is difficult to correct the leakage.<sup>2</sup>

In 1983, Ohtsuka *et al* reported a new method of anterior decompression using a posterior approach.<sup>3</sup> This method consisted of two procedures: 1) a wide laminectomy including the excision of pedicles, and 2) drilling of the vertebral bodies from the posterolateral direction to the anterior aspect of the spinal cord. Using this method, decompression extending over up to four spinal segments became possible. In the present case, OPLL was present at six spinal segments from T3 to T8. Thus, we selected Ohtsuka's method for the initial approach and started to extirpate the OPLL. During drilling of the vertebral body, however, electrophysiologic monitoring indicated a considerable risk of spinal cord damage. Based on this episode, we had to suspend the OPLL extirpation and finish the surgical treatment as a wide laminectomy.

Yonenobu *et al* reported that kyphotic deformities occurred in 3 of 19 patients who underwent laminectomy for thoracic OPLL.<sup>2</sup> In these cases, deformities were detected from 10 to 84 months after surgery, unlike our case where kyphosis progressed and myelopathy worsened in the early stage after laminectomy. We suggest that the differences in outcome may be related to the amount of resection volume of the facets. In Ohtsuka's method, a wide resection of facets is required, possibly increasing the occurrence of instability.

When we planned the rescue surgery for the postoperative paraparesis in this case, we questioned whether ABF would be a safe and effective procedure. Yonenobu *et al* performed ABF as the second surgery for 3 patients with thoracic OPLL who deteriorated after laminectomy, but all 3 patients became paraplegic after ABF.<sup>2</sup> Ohtani *et al* also reported that ABF did not produce favorable results when it was performed on thoracic OPLL patients whose myelopathy was worsened after laminectomy.<sup>1</sup> We considered the possibility that the severely damaged spinal cord potentially resulting after laminectomy could not tolerate the procedure of OPLL extirpation through anterior approach.



In the present case, taking into account the risks associated with ABF,<sup>1,2</sup> we initially used a posterior instrumented fusion. With the instrumented fusion, we expected to prevent further progression of neurologic deterioration by stabilizing the spinal column in the affected area. We planned to add ABF after any damage to the spinal cord had time to heal somewhat. Although we did not correct the kyphosis, the patient's sensory and motor loss began to recover before the ABF surgery was implemented. Thus, we suggest that the instability of the spinal column caused by laminectomy contributes to the potential for neurologic deterioration. In addition, to our surprise, the patient's neurologic recovery steadily progressed after the instrumented fusion. The degree of the recovery was greater than we expected, finally resulting in full neurologic recovery. Furthermore, this neurologic recovery persisted for 15 years, despite the presence of residual anterior impingement of the cord by OPLL.

The experience of this case leads us to propose that kyphosis and instability are major factors potentially affecting the severity of thoracic myelopathy, and posterior fusion with spinal instrumentation is a safe and effective adjunct procedure for thoracic OPLL patients even if anterior compression of the cord by OPLL remains. In thoracic OPLL patients in whom spinal cord damage is severe and/or extirpation of OPLL has a great risk, one-stage operation of posterior decompression and instrumented fusion may be an optimal choice for surgical treatment.

### ■ Key Points

- Postoperative paraparesis occurred after laminectomy for thoracic myelopathy resulting from ossification of the posterior longitudinal ligament and was markedly reversed after an additional posterior instrumented fusion.
- Kyphosis and instability are major factors that affect the severity of thoracic myelopathy resulting from ossification of the posterior longitudinal ligament.
- Posterior fusion with spinal instrumentation is a safe and effective adjunct procedure for surgical treatment of thoracic ossification of the posterior longitudinal ligament.

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