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Clinical Studies

Proximal junctional acute collapse cranial to multi-level lumbar fusion: a cost analysis of prophylactic vertebral augmentation

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Abstract

BACKGROUND CONTEXT: Limited data are available regarding incidence of proximal junctional acute collapse after multilevel lumbar spine fusion. There are no data regarding the cost of prophylactic vertebral augmentation adjacent to long lumbar fusions compared with the costs of performing revision fusion surgery for patients suffering with this complication.

PURPOSE: To perform a cost analysis of prophylactic vertebral augmentation for prevention of proximal junctional acute collapse after multilevel lumbar fusion.

STUDY DESIGN: Retrospective chart review and cost analysis.

PATIENT SAMPLE: All female patients older than 60 years undergoing extended lumbar fusions were reviewed to establish the incidence of proximal junctional acute collapse.

OUTCOME MEASURES: Cost estimates for two-level vertebroplasty, two-level kyphoplasty, and revision instrumented fusion were calculated using billing data and cost-to-charge ratios.

METHODS: Cost comparisons of prophylactic vertebral augmentation versus extension of fusion for patients suffering from proximal junctional acute collapse were performed.

RESULTS: Twenty-eight female patients older than 60 years underwent lumbar fusions from L5 or S1 extending to the thoracolumbar junction (T9–L2). Fifteen of the 28 patients had prophylactic vertebroplasty cranial to the fused segment. Proximal junctional acute collapse requiring revision surgery occurred in 2 of the 13 patients (15.3%) treated without prophylactic vertebroplasty. None of the 15 patients undergoing cement augmentation experienced this complication. Assuming a 15% decrease in the incidence of proximal junctional acute collapse, the estimated cost to prevent a single proximal junctional acute collapse was $46,240 using vertebroplasty and $82,172 using kyphoplasty. Inpatient costs associated with a revision instrumented fusion averaged $77,432.

FDA device/drug status: approved for this indication (pedicle screws); approved but not for this indication (kyphoplasty/vertebroplasty) (authors RAH, SLB).

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CONCLUSIONS: Prophylactic vertebral augmentation for the prevention of proximal junctional acute collapse may be a cost effective intervention in elderly female patients undergoing extended lumbar fusions. Further efforts are needed to determine more precisely the incidence of proximal junctional acute collapse and the effects of various risk factors on increasing this incidence, as well as methods of prevention.

Keywords: Vertebroplasty; Kyphoplasty; Proximal junctional acute collapse; Complications; Spine fusion

Introduction

Adjacent segment problems are well documented after lumbar spinal fusion [1–7]. Biomechanical testing has shown that the increased stiffness of the fused spinal segment increases loads and motion within adjacent segments [5,7–14]. In some elderly and osteoporotic patients, decreased bone strength in the face of these increased loads leads to proximal junctional acute collapse in the early postoperative course [1,15].

Proximal junctional acute collapse, sometimes referred to as ‘‘topping-off syndrome,’’ is a well-described complication of extended lumbar spine fusions [1,5,15,16]. Length of the fusion construct, reduced sagittal plane lordosis, female gender, age older than 60 years, and presence of osteoporosis have been reported to increase the risk of this complication [1,15]. Given the frequent need for extension of instrumentation and fusion beyond the failed vertebrae, the occurrence of proximal junctional acute collapse has clear clinical significance. Despite this, information regarding the incidence and avoidance of this complication remains limited.

Vertebroplasty is a percutaneous procedure performed to stabilize vertebral insufficiency fractures and augment the mechanical strength of the fractured vertebral bodies. When an inflatable bone tamp is used for this procedure it is generally referred to as kyphoplasty (Kyphon Inc., San Francisco, CA). A number of reports have demonstrated significant pain relief with limited complications in most patients undergoing these procedures for osteoporotic vertebral compression fractures [17–23].

A recent biomechanical study has suggested a possible role for prophylactic vertebral augmentation in cases where severe osteoporosis may increase the risk of further fractures of the spine adjacent to fractured vertebrae treated via kyphoplasty or vertebroplasty [24]. The authors are aware of no study assessing the value of vertebral augmentation as a prophylactic measure in elderly or osteoporotic patients undergoing extended lumbar spine fusion.

This study is a retrospective chart review of female patients older than 60 years undergoing extended lumbar fusions ending cranially within the thoracolumbar junction (T9–L2). We sought to determine the incidence of proximal junctional acute collapse with and without prophylactic vertebral augmentation. These incidence data, along with cost data from our institution, are used to compare the costs associated with routine prophylactic vertebral augmentation versus revision instrumented spinal fusion only for those patients experiencing proximal junctional acute collapse. We hypothesize that routine prophylactic vertebral augmentation is cost effective in this patient population in comparison to the costs of revision fusion surgery for those patients suffering with this complication.

Materials and methods

We reviewed the radiographic and clinical records of a consecutive series of female patients older than 60 years undergoing instrumented lumbar fusions extending from L5 or S1 proximally to the thoracolumbar junction (T9–L2). All fusion procedures were performed by a single surgeon (RAH). Abstracted information included whether prophylactic vertebral augmentation had been performed and whether proximal junctional acute collapse occurred during the first 6 months postoperatively. Indications for the index surgery, patient age, and details of surgical procedures were reviewed. All procedures were performed using rigid, segmental pedicle screw-based instrumentation with interbody fusion used selectively for lordosis restoration and improved fusion rate.

Hospital, surgeon, and anesthesia cost data at our institution were determined for two-level vertebroplasty and kyphoplasty performed for osteoporotic compression fractures. In addition, the inpatient treatment costs associated with revision instrumented fusion for proximal junctional acute collapse were calculated [25–28]. Direct and indirect hospital costs, including all nonphysician services, were determined using Siemens SQL software (Munich, Germany). All two-level vertebroplasties and kyphoplasties done at our institution between January 2004 and February 15, 2006 were used to determine the average hospital costs for vertebroplasty and kyphoplasty. Surgeon and anesthesia costs were determined using Medicare Common Procedural Terminology—Relative Value Units (CPT-RVUs) and the conversion factor in dollars per RVU specific to the department performing the procedure. These costs were added to determine the total cost for each procedure (Fig. 1).

Using a simple cost-analysis model, the cost of preventing a single adjacent segment failure in extended lumbar fusion patients via prophylactic vertebroplasty or kyphoplasty was determined using our incidence data for proximal junctional acute collapse and cost estimates for the vertebral augmentation procedures, as well as revision fusion

Hospital charges x DRG cost to charge ratio

+

Surgeon charges (CPT-RVU x conversion factor)

+

Anesthesia charges (CPT-RVU x conversion factor)

=

Total cost of procedure

Fig. 1. Equation used to determine the costs of two-level vertebroplasty, two-level kyphoplasty, and revision fusion surgery.

surgery. A sensitivity analysis was done to determine the progressive effect of reductions in the incidence of adjacent segment failure via prophylactic vertebral augmentation on total cost [28–30].

Results

Fifteen female patients with an average age of 73.9 years (range=60–87) underwent extended lumbar fusion followed by prophylactic vertebroplasty of either two or three cranial adjacent vertebrae (Table 1). There were no complications related to the vertebroplasty procedure. None of these patients required revision spinal surgery during the follow-up period. Two patients did suffer a vertebral compression fracture at the level immediately cranial to the fusion, which did not collapse beyond the cement core and produced no noticeable symptoms (Fig. 2).

Thirteen patients, with an average age of 67.3 years (range=60–77), underwent extended fusions without prophylactic vertebral augmentation. Two of these 13 patients (15.4%) suffered proximal junctional acute collapse requiring extension of instrumented fusion to T2, one at 3 weeks and one at 3 months postoperatively (Fig. 3). One additional patient experienced a compression fracture of the cranial vertebra, which healed without intervention or clinical effect. The two patient groups were well matched in terms of age, medical comorbidities, incidence of osteoporosis, and length of follow-up (Table 1).

Average total hospital, surgeon, and anesthesia costs for a two-level vertebroplasty or kyphoplasty at our institution were $6,936 and $12,326, respectively. Total inpatient costs for the two patients undergoing extension of fusion for proximal junctional acute collapse averaged $77,432.

The cost to prevent a single adjacent segment failure given the set costs of vertebroplasty or kyphoplasty at our institution and assuming a reduction in the incidence of adjacent segment failure of 15% is $46,240 and $82,172, respectively. A sensitivity analysis shows the effect of varying the reduction in incidence of proximal junctional acute collapse (Fig. 4). The break-even cost point in terms of a required reduction in incidence of proximal junctional acute collapse using these cost data is 8.9% for vertebroplasty and 15.9% for kyphoplasty.

Discussion

Fusion with pedicle screw instrumentation for degenerative conditions affecting the lumbar spine has been increasingly performed in recent years [31,32]. As the American population ages, the number of individuals with osteoporosis is also increasing [31,32]. Given these trends, it is likely that the incidence of proximal junctional acute collapse will also increase [1–5,31,32].

In the present study, 15 female patients older than 60 years underwent extended fusion followed by prophylactic augmentation of the cranial vertebral segments adjacent to

Table 1
Demographics of patient cohorts with and without vertebral augmentation

		Vertebral augmentation patients	Nonaugmentation patients
Average age (range)		73.9 y (60–87)	67.3 y (60–77)
Average follow-up (range)		17.3 mo (12–44)	15.5 mo (13–49)
Osteoporosis confirmed by DEXA		1/15	0/13
Number of patients with medical comorbidities[a]		5/15	5/13
Indication for surgery	Adjacent segment stenosis	7	8
	Scoliosis	6	5
	Multilevel instability	2	0
Cranial level of instrumentation	T9	0	1
	T10	1	10
	T11	1	0
	L1	2	1
	L2	10	1
Incidence of adjacent segment vertebral collapse		0% (0/15)	15.4% (2/13)

[a] Comorbidities include congestive heart failure, prior myocardial infarction, coronary artery disease, valve disease, chronic obstructive pulmonary disease, restrictive lung disease, renal insufficiency, hepatic insufficiency, and morbid obesity. No patient had no more than one comorbidity.

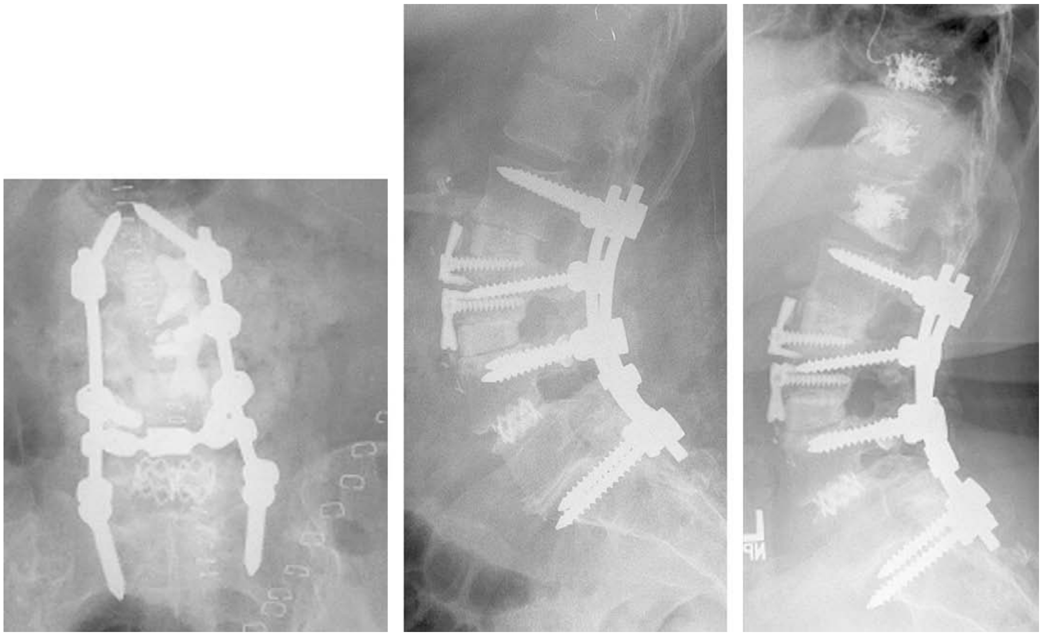

Fig. 2. (Left) Antero-Posterior (AP) radiograph prevertebroplasty. Patient underwent L2–L4 fusion because of adjacent segment instability after postlaminectomy spondylolysis. (Middle) Lateral radiograph prevertebroplasty. (Right) Lateral radiograph demonstrating L1 compression fracture, which occurred approximately 8 weeks after fusion. This fracture did not significantly collapse and had no effect on the patient's clinical recovery or outcome.

their fusions. None of these patients experienced proximal junctional acute collapse. Clinical outcomes for these patients compared favorably with the cohort of extended fusion patients treated without vertebral augmentation, 15% of whom (2/13) experienced a proximal junctional acute collapse requiring revision instrumentation and fusion to T2.

Aside from the obvious clinical benefit of preventing adjacent segment failure, our simple cost-comparison model demonstrates that routine prophylactic vertebral augmentation can be cost effective when compared with the economic costs of revision surgery, when required. Our data indicate that if prophylactic vertebroplasty reduces the incidence of proximal junctional acute collapse by approximately 9%, the overall costs are comparable to those of revision extension of the fusion performed only for those patients experiencing proximal junctional acute collapse. The analogous reduction in incidence of adjacent sequent vertebral collapse required to make two-level prophylactic kyphoplasty cost neutral would be approximately 16%.

The small number of patients requiring revision and the lack of complete cost data including rehabilitation and follow-up care is a limitation of our analysis. It is important to note, however, that our cost data for patients requiring revision fusion likely underestimate total costs, as these patients also experience greater needs for posthospitalization care such as rehabilitation, pain medications, and skilled nursing care. In addition, our cost data for kyphoplasty and vertebroplasty likely overestimate the costs of these procedures if they are performed either as part of the initial fusion procedure or during the initial postoperative hospitalization. Thus, our analysis of the relative costs of prophylactic augmentation in this clinical setting should be a conservative estimate.

Another limitation is that our data regarding the incidence of adjacent segment failure with and without vertebroplasty are derived from a limited number of patients, with substantial differences between our patient groups in terms of cranial fusion level. This reflects our practice of not augmenting cranial vertebrae in patients fused across the thoracolumbar junction, which is generally considered to be more protective of adjacent segments than ending a fusion at T12 or L1. Given the incidence data presented here, we now perform prophylactic augmentation in these patients as well. It is also important to realize that this limitation is mitigated in the cost analysis by using the reduction in incidence of proximal junctional acute collapse as the independent variable. Thus, our analysis provides information on costs for any reduction achieved in incidence of proximal junctional acute collapse. Further, the 15% incidence of adjacent segment collapse reported here is consistent with incidence data reported by other authors [16,33].

The optimum number and levels of vertebrae selected for prophylactic vertebroplasty remains undetermined. Our current practice is to include the upper level of instrumentation along with the first level cranial to the fusion construct. Although these choices remain somewhat arbitrary, they are based on clinical observations of patterns of proximal junctional acute collapse, most of which occur at one of these two vertebrae [16,33].

Concerns remain regarding the long-term risk of vertebroplasty as a potential locus for hematogenous infection

Fig. 3. (A) Lateral thoracolumbar spine radiograph after revision fusion procedure. Patient had extension of instrumented fusion to T10 because of high-grade stenosis above prior L3–S1 fusion. (B) Postoperative Antero-Posterior (AP) thoracolumbar spine radiograph after index fusion procedure. (C) Lateral thoracic spine radiograph demonstrates collapse of the T10 vertebrae with pullout of cranial pedicle screws. (D) Sagittal computed tomograph reconstruction showing collapse of proximal fused spinal segment. (E) Lateral radiograph after extension of instrumentation to T2 for proximal junctional acute collapse. (F) Postoperative AP radiograph.

[34,35]. In addition, the use of bone cement in this fashion could potentially reduce the nutrient supply to adjacent intervertebral discs, and thus accelerate disc degeneration in patients undergoing vertebroplasty [36,37]. Although proximal junctional acute collapse is an early complication of extended lumbar fusion, degenerative disease and adjacent segment stenosis as a longer-term concern, and may potentially be increased is a result of this technique.

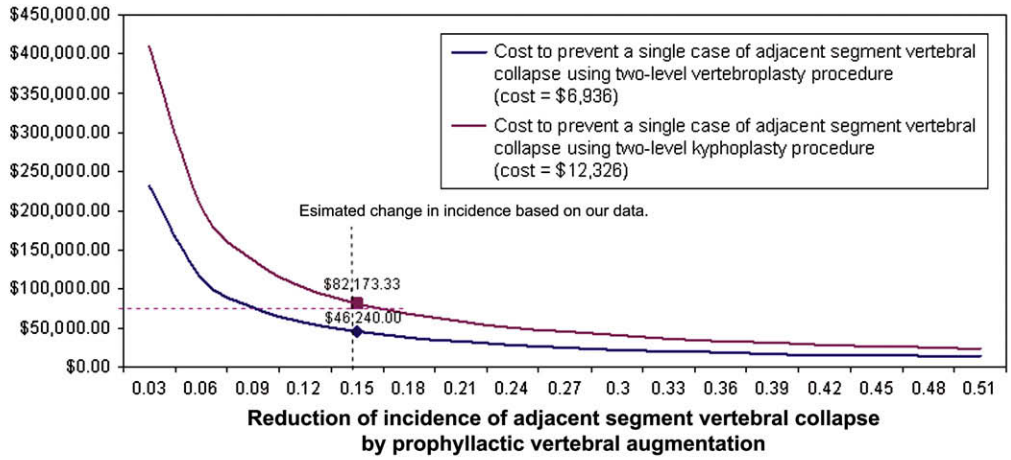

Fig. 4. Cost to prevent a single adjacent segment failure while varying the reduction of incidence. As the incidence of proximal junctional acute collapse decreases, the cost of preventing a single occurrence of adjacent segment collapse increases. The cost of preventing an adjacent segment collapse also depends on the cost of the prophylactic augmentation procedure. The trend lines correspond to the cost of two-level vertebroplasty (cost=$6,936) and two-level kyphoplasty (cost=$12,326). The horizontal dashed line corresponds to the average cost of open revision surgery ($77,431). The vertical dashed line corresponds to a reduction in the incidence of proximal junctional acute collapse of 15%.

Most of the patients in our study group did not undergo Dual-energy x-ray absorptiometry (DEXA) scans before their fusion surgery. It may be that such diagnostic studies would allow better definition of the patient group appropriately indicated for prophylactic treatment based on a given patient's bone mineral density. However, the available data regarding fracture vulnerability based on DEXA values does not include the added mechanical effect of an adjacent instrumented fusion [15]. Given the altered mechanics, spine fusion patients may well be at risk of adjacent vertebral collapse even with bone mineral densities that are above the osteoporotic range. In addition, bone density is a dynamic value. Thus, elderly patients without osteoporosis at the time of fusion may progressively increase their fracture risk with progressive loss of bone mineral content.

The phrase ''proximal junctional kyphosis'' (PJK) denotes the development of kyphosis immediately above a spinal fusion. This can result from degenerative disease within the facet joints and disc, as well as because of compression fractures of the cranial adjacent or upper-instrumented vertebra [38,39]. The phenomenon we describe here as ''proximal junctional acute collapse'' is distinct from PJK in that the clinical impact is more severe due to the extent of the deformity, mechanical instability, and pain resulting from the fracture [40]. The failures we are describing are also a more acute postoperative occurrence than the traditional definition of PJK.

In conclusion, vertebral augmentation appears to be a safe technique to prophylactically increase the mechanical strength of vertebral bodies. Our data suggest that female patients older than 60 years undergoing lumbar instrumented fusions may benefit from prophylactic vertebroplasty or kyphoplasty as a means of avoiding proximal junctional acute collapse. Even leaving aside considerations of the pain and risks associated with revision fusion surgery, the relative costs of prophylactic vertebral augmentation procedures appear to support their cost effectiveness in this patient population.

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