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Cost and quality of life outcome analysis of postoperative infections after subaxial dorsal cervical fusions

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OBJECT Infections following spine surgery negatively affect patient quality of life (QOL) and impose a significant financial burden on the health care system. Postoperative wound infections occur at higher rates following dorsal cervical procedures than ventral procedures. Quantifying the health outcomes and costs associated with infections following dorsal cervical procedures may help to guide treatment strategies to minimize the deleterious consequences of these infections. Therefore, the goals of this study were to determine the cost and QOL outcomes affecting patients who developed deep wound infections following subaxial dorsal cervical spine fusions.

METHODS The authors identified 22 (4.0%) of 551 patients undergoing dorsal cervical fusions who developed deep wound infections requiring surgical debridement. These patients were individually matched with control patients who did not develop infections. Health outcomes were assessed using the EQ-5D, Pain Disability Questionnaire (PDQ), Patient Health Questionnaire (PHQ-9), and visual analog scale (VAS). QOL outcome measures were collected preoperatively and after 6 and 12 months. Health resource utilization was recorded from patient electronic medical records over an average follow-up of 18 months. Direct costs were estimated using Medicare national payment amounts, and indirect costs were based on patients' missed workdays and income.

RESULTS No significant differences in preoperative QOL scores were found between the 2 cohorts. At 6 months postsurgery, the noninfection cohort had significant pre- to postoperative improvement in EQ-5D ($p = 0.02$), whereas the infection cohort did not ($p = 0.2$). The noninfection cohort also had a significantly higher 6-month postoperative EQ-5D scores than the infection cohort ($p = 0.04$). At 1 year postsurgery, there was no significant difference in EQ-5D scores between the groups. Health care–associated costs for the infection cohort were significantly higher ($16,970 vs $7658; $p < 0.0001$). Indirect costs for the infection cohort and the noninfection cohort were $6495 and $2756, respectively ($p = 0.03$). Adjusted for inflation, the total costs for the infection cohort were $21,778 compared with $9159 for the noninfection cohort, reflecting an average cost of $12,619 associated with developing a postoperative deep wound infection ($p < 0.0001$).

CONCLUSIONS Dorsal cervical infections temporarily decrease patient QOL postoperatively, but with no long-term impact; they do, however, dramatically increase the cost of care. Knowledge of the financial burden of wound infections following dorsal cervical fusion may stimulate the development and use of improved prophylactic and therapeutic techniques to manage this serious complication.

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KEY WORDS postoperative infection; cervical spine; cost; quality of life

ABBREVIATIONS BMI = body mass index; DCF = dorsal cervical fusion; EMR = electronic medical record; MCID = minimum clinically important difference; PDQ = Patient Disability Questionnaire; PHQ-9 = Patient Health Questionnaire; PRO = patient-reported outcome; QOL = quality of life; SF-36 = 36-Item Short Form Health Survey; VAS = visual analog scale.

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Postoperative wound infections are common and serious complications of spine surgery, occurring in 0.5%–20% of cases depending on location, case complexity, instrumentation, approach, and comorbidities.[4,6,8,30,34] Postoperative spinal infections present a challenge to surgeons, as they require urgent diagnosis and management to prevent deleterious sequelae, such as acute neurological decompensation, osteomyelitis, pseudarthrosis, and epidural abscess.[12,19] Accordingly, their management must be aggressive, often requiring surgical debridement, additional imaging and laboratory tests, and culture-directed parenteral antibiotic therapy.[2,15]

The dorsal surgical approach to the cervical spine has a 4.5%–9% postoperative infection rate compared with a 0%–1% rate associated with a ventral approach.[3,7,17,21] Whereas preoperative risk factors for postoperative cervical infections (including smoking, diabetes, and intraoperative blood loss) have been investigated, few studies have assessed the quality of life (QOL) and hospital costs associated with these infections.[24,33] Quantifying cost and QOL parameters will help assess the utility of prophylactic and postoperative management strategies for postoperative wound infections. In the present study, we analyzed patient-reported outcome (PRO) data as well as direct and indirect cost information to assess the impact of deep wound infections following dorsal cervical fusion (DCF). We hypothesized that patients with wound infections following DCF would report decreased QOL and incur elevated health care costs.

Methods

Demographics

We retrospectively reviewed electronic medical records (EMRs) for demographic and QOL outcome data. All patients who underwent dorsal cervical spine fusions from 2008 to 2012 were identified. Included were patients with a minimum 5-month follow-up who experienced a deep wound infection as defined by the Centers for Disease Control and Prevention.[16] This criterion includes that the infection occurred within 1 year of surgery, involved deep soft tissues of the incision, and demonstrated at least 1 of the following: purulent drainage from the deep incision, spontaneous or deliberate surgical dehiscence in the setting of a fever or localized pain or tenderness, abscess visualization during examination or reoperation, and diagnosis of deep incisional surgical site infection by a surgeon or attending physician. After identifying the infection cohort, the included patients were individually matched to control patients of the same sex, age ± 5 years, body mass index (BMI) ± 5 kg/m^2, same operating surgeon, same instrumentation, date of surgery ± 2 years, and duration of follow-up. Where possible, we also controlled for cervical levels operated on; comorbidities including hypertension, coronary artery disease, hyperlipidemia, and diabetes; and preoperative medications.

Health Measurement Data

Patient-reported outcomes (that is, EQ-5D, visual analog scale [VAS], Patient Health Questionnaire [PHQ-9], and Pain Disability Questionnaire [PDQ]) were established through the institutional Knowledge Program. The Knowledge Program is a patient-derived outcome assessment tool embedded in our EMR that prospectively compiles self-assessment data taken at each outpatient visit. The PRO metrics used in this study have all been validated to evaluate patient QOL after spinal surgery.[28] The EQ-5D is an instrument designed to measure and standardize health outcomes. Its values are transformed into an index value known as the quality-adjusted life year, which is a number between 0 and 1, where 1 is equivalent to 1 year in perfect health and 0 is equivalent to patient death.[10] The PDQ uses an 11-point (0–10) scale to assess how pain affects the patient's ability to function in 15 categories. It is subdivided into functional and psychosocial components, which are combined to give a total score with a maximum of 150 points (higher scores indicate greater levels of disability).[13] The PHQ-9 arguably screens for depression based on the 9 criteria established by the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition*, with scores between 5 and 10 indicative of minor depression and scores higher than 10 indicative of major depression.[18] The minimum clinically important differences (MCIDs) for the EQ-5D, VAS, PDQ, and PHQ-9 values at 1 year were 0.1, 2.6, 26, and 5, respectively.[22]

Cost Data

Direct health care cost calculations were collected using the EMR and incorporated postoperative hospital stay, surgery, laboratory, imaging, physical and occupational therapy, and outpatient visits. Outpatient visits, therapy, imaging, and medication costs were collected for a maximum of 2 years postoperatively; follow-up time was matched between the infection and control cohorts. Laboratory costs were collected for 6 months postoperatively to account for tests related to extended antibiotic therapy. Medicare national payment amounts were used to calculate and standardize direct cost data and reflect the charges associated with health care payers. Direct health care costs were calculated based on the primary diagnosis-related group, and national Medicare payment amounts were found in *DRG Expert*.[9] Current Procedural Terminology codes for the original surgery, repeat surgery, laboratory tests, imaging, therapy, and outpatient visits were used to calculate costs based on the 2013 physician fee reimbursement schedule obtained from the Center for Medicare and Medicaid Services.[5] Medication costs were collected from the 2007 *Red Book*.[25] To estimate the indirect costs, the median annual household income based on the patient's zip code was converted into a daily wage, which was multiplied by the patient self-reported missed workdays.[1] Cost data were standardized to 2013 dollars using inflation data from the United States Department of Labor Bureau of Labor Statistics (http://www.bls.gov/cpi/cpi_dr.htm#2013).

Statistical Analysis

Data were analyzed using JMP pro 10 statistical software (SAS Institute). Descriptive statistics summarizing patient demographics are presented as means ± SDs or counts with percentages as appropriate. Paired t-tests and Wilcoxon signed-rank tests were used for parametric and nonparametric data, respectively, to ascertain significance in the pre- to postoperative PRO score change for each patient for the respective questionnaire. The infection and noninfection cohorts were compared with respect to numeric variables using independent-sample t-tests and categorical variables using Fisher exact tests. Values of $p < 0.05$ were considered statistically significant.

Results

Demographics

Five hundred fifty-one patients underwent DCF at our institution between 2008 and 2012. From this population, 29 patients (5.2%) were identified as having an infection, with 22 patients (3.9%) meeting the criteria of having a postoperative deep infection (Table 1). The average time to infection was 17 days. Both the infection cohort and the matched controlled cohort comprised 13 men (59%) and 9 women (41%), average age was 60 years, average BMI was 29.8, and average follow-up time was 18 months. There were no statistically significant differences between the infection and noninfection cohorts for any of the demographic or operative variables collected. Of 100 additional patients identified from the larger 551-patient cohort, there were no significant differences in age, BMI, medications, comorbidities, or smoking status compared with the control cohort used in this study.

Patient-Reported Outcomes

Preoperatively, the cohorts were not statistically different in terms of EQ-5D, VAS, PDQ, and PHQ-9 values (Table 2). At 6 months, the noninfection cohort demonstrated pre- to postoperative improvement that was significant with EQ-5D (p = 0.02), VAS (p = 0.03), and PDQ (p = 0.007) and trended toward significance with PHQ-9 (p = 0.08). At 12 months, the noninfection cohort showed significant improvements with PDQ (p = 0.02) and PHQ-9 (p = 0.03) and improvements of marginal significance with EQ-5D (p = 0.06). The infection cohort showed significant pre- to postoperative improvement with PHQ-9 (p = 0.02) at 6 months and with EQ-5D (p = 0.03) and PHQ-9 (p = 0.03) at 12 months. The only significant difference between the 2 cohorts was seen at 6 months, when the EQ-5D score was significantly greater for the noninfection cohort compared with the infection cohort (0.69 vs 0.54, p = 0.04). At 12 months, there were no statistically significant differences in QOL outcomes between the cohorts. There were no significant differences between the cohorts in terms of percentage achieving an MCID at 1 year.

TABLE 1. Demographic information for infection and noninfection cohorts*

Variable	Infection	Noninfection	p Value†
No. of patients	22	22	
Age at surgery (yrs)	60.0 ± 13.2	60.2 ± 11.0	0.9
Male sex	13 (59)	13 (59)	0.99
BMI (kg/m^2)	29.7 ± 5.0	29.8 ± 6.6	0.9
Steroid medication	7 (32)	6 (28)	0.7
Antiinflammatory medication	13 (59)	12 (55)	0.8
Hypertension	15 (68)	11 (50)	0.2
Dyslipidemia	10 (45)	9 (41)	0.8
Coronary artery disease	4 (18)	3 (14)	0.7
Diabetes	5 (23)	4 (18)	0.7
Smoker	13 (59)	12 (55)	0.8
Smoking history (yrs)	11 ± 11	11 ± 14	0.9
Treated cervical levels			
1–2	5	4	0.48
≥3	17	18	

* Values are expressed as mean ± SD for continuous variables and number (%) for categorical values.

† Student t-test was used for continuous variables and Fisher exact test for categorical variables.

Costs

The cost of the initial surgery was $5731 for both infection and noninfection cohorts. The additional hospital and surgical costs for postoperative wound infections averaged $7062. Postoperative costs, including laboratory tests, medications, imaging, and therapy, were $5200 ± $3931 for the infection cohort and $1670 ± $1298 for the noninfection cohort (p = 0.0005) (Table 3). Direct health care costs (surgery and postoperative costs) for patients with a postoperative infection were $16,970 ± $4375 compared with $7658 ± $2625 (p < 0.0001) for those without an infection (Table 4). Patients with postoperative infections missed an average of 38 days of work, whereas those without postoperative infections missed an average of 15 days. The indirect cost for the infection cohort was $6495 ± $4769, and that for the noninfection cohort was $2756 ± $3563 (p = 0.03). When adjusted for inflation to 2013 dollars, the total cost for the infection cohort was $21,778 ± $5625, whereas that for the noninfection cohort was $9159 ± $4087. For the infection cohort, 1- to 2-level fusions were associated with a total hospital cost of $14,125 ± $2139 compared with fusions of 3 or more levels, which were $17,807 ± $4550 (p = 0.09). Total hospital costs were $21,265 ± $2953 for the 1- to 2-level fusion group and $21,929 ± $5701 for the 3-level fusion group (p = 0.82).

Discussion

The financial and QOL implications of postsurgical dorsal cervical infections for patients are poorly characterized in the literature. Although the previously described infection rates of 4.5%–9%[8,34] have remained relatively constant, the increasing frequency of dorsal cervical surgeries has resulted in a greater absolute number of infections after spinal surgery.[7] The present study was performed to define the impact that infections have on patients undergoing DCF surgery from a QOL and financial perspective. We hypothesized that a deep wound infection following DCF would increase both direct and indirect costs while decreasing patient QOL.

We were unable to identify previous studies that directly evaluated cost and QOL outcomes solely after dorsal cervical surgery. However, controversy exists regarding the patient outcomes following postoperative noncervical spinal infections. In a recent retrospective study that fol-

TABLE 2. Patient-Reported Outcomes*

Metric	Preoperative			6 Mos				12 Mos			
	No.	Score	p Value†	No.	Score	p Value‡	p Value†	No.	Score	p Value‡	p Value †
EQ-5D			0.52				0.04§				0.6
Infection	14	0.5		12	0.54	0.16		12	0.68	0.03§	
Noninfection	21	0.55		14	0.69	0.02§		21	0.63	0.06	
VAS			0.31				0.84				0.68
Infection	17	4.94		14	4.43	0.09		15	5.07	0.34	
Noninfection	22	5.95		16	4.19	0.03§		22	5.5	0.19	
PDQ			0.26				0.36				0.97
Infection	14	95		12	76	0.06§		12	69	0.08	
Noninfection	19	83		15	64	0.007§		15	69	0.02§	
PHQ-9			0.81				0.8				0.78
Infection	14	8.64		10	6.4	0.02§		10	5.4	0.03§	
Noninfection	18	8.06		14	5.79	0.08		18	6.1	0.03§	

* Matched pair t-test was used to determine significance for postoperative values compared to preoperative values. Student t-test was used to determine significance for differences between infection and noninfection cohorts.
† Difference between infection and noninfection cohorts.
‡ Pre- and postoperative PRO values within the cohorts.
§ $p \leq 0.05$.

lowed up 30 patients for 2 years postoperatively, Petilon et al.[23] found that patients diagnosed with deep wound infections following dorsal lumbar fusion had significantly worse back pain and were less likely to achieve MCID as measured by the Oswestry Disability Index 2 years postoperatively. They did not, however, identify significant differences for overall QOL as measured by the 36-Item Short Form Health Survey (SF-36). In a prospective study evaluating infections following lumbar arthrodesis, Falavigna et al.[11] found no difference in Oswestry Disability Index, SF-36, numerical rating scale, or Beck Depression Inventory values at the 2-year time point between patients with infections compared to those without. In the present study, we found that at 6 months postoperatively, the noninfection cohort had a statistically significantly improved QOL compared with the infection cohort. This same trend was also seen with the VAS and PDQ measures, showing a significant pre- to postoperative improvement for the noninfection cohort that was not seen for the infection cohort. Whereas the development of a postoperative deep wound infection led to worse clinical outcomes at 6 months, differences between the infection and noninfection cohorts disappeared at the 1-year time point for all questionnaires. Using these validated outcome measures, we were able to investigate the short-term and longer-term QOL outcomes data to establish the impact of a postoperative dorsal cervical infection. Our findings show that although there may be a short-term impact on QOL, by 1 year, a postoperative infection does not affect QOL. These findings are similar to those of previous lumbar fusion studies.[11,23]

Although the long-term impact of postoperative dorsal cervical infection on QOL is minimal, these complications substantially increase the financial burden to the patient and the health care system. In a time of increased fiscal consciousness, federal departments and hospitals are attempting to minimize recovery costs and preventable complications. Whereas the true cost of these infections is difficult to ascertain, methods have been established to estimate and standardize direct and indirect costs across different providers and states.[1,20,31] In our study, we found the average direct health care cost of dorsal cervical infec-

TABLE 3. Postoperative costs*

Parameter	Cost in US $		p Value†
	Infection	Noninfection	
Medications	1574 ± 2623	119 ± 188	0.01‡
Lab tests	595 ± 381	120 ± 73	<0.0001‡
Imaging	1730 ± 2011	836 ± 1103	0.07
Therapy	1120 ± 975	758 ± 161	0.05‡
Total	5200 ± 3931	1670 ± 1298	0.0003‡

* Values are expressed as mean ± SD. Total medication costs include costs associated with antibiotics and pain management. Laboratory costs include complete blood counts, blood and urine cultures, basic metabolic panel, erythrocyte sedimentation rate, and C-reactive protein, among others. Imaging costs include radiographs, CT scans, and MR images associated with the cervical or thoracic spine. Therapy costs include both inpatient therapy and outpatient spine visits.
† Student t-test.
‡ $p \leq 0.05$.

TABLE 4. Direct, indirect, and total costs

Cost Parameter	Cost in US $ (n = mean missed workdays)		p Value*
	Infection	Noninfection	
Direct health care cost	17,552 ± 4732	7660 ± 2685	<0.0001
Indirect cost	6495 ± 4769 (38)	2756 ± 3563 (15)	0.03
Adjusted cost†	21,778 ± 6403	9159 ± 4184	<0.0001

* Student t-test was used to derive p values.
† Adjusted cost was the combination of direct and indirect cost converted to 2013 dollars.

tion to be $17,552. Similarly, in a retrospective study of 292 patients with infection following instrumented dorsal lumbar fusion, McGirt et al.[20] found the direct cost to be $15,817. This suggests that the location of the infection may have little impact on the cost. In a 2012 study evaluating the short-term direct hospital costs of spinal complications, Whitmore et al.[32] found a cost increase of $4067 for 30 days after a deep wound infection. The difference between their findings and the $12,619 increase found in our study is likely due to the longer follow-up time of the present study.

In addition to greater direct hospital costs, the patients with postoperative infections had more missed workdays. Our analysis found that the infection cohort had 23 additional missed workdays on average, which translated to $3739 more in lost wages for these patients. Including indirect costs, we found that the total cost adjusted for inflation was $21,778 in the infection cohort compared with $9159 in the noninfection cohort. This reflects an average cost of $12,619 for an infection following DCF, with an average 18-month follow-up.

In our study, we found that infections following DCF led to significantly increased health care, societal, and patient costs, as well as short-term decrements in QOL. Additional studies of infection following spinal surgery have corroborated the dramatically increased cost, and some have shown decreased QOL.[20,23,32] In light of these findings, efforts are being made to reduce the prevalence of wound infections following spinal surgery. One recent study found that infection rates following posterior lumbar fusions decreased from 3.35% to 0.48% with removal of an outer pair of gloves before handling instrumentation.[26] Additionally, several studies have shown that prophylactic intraoperative application of powdered vancomycin in addition to preoperative intravenous cefazolin significantly decreased postoperative infection rates.[14,27] One study comparing 911 patients receiving preoperative cefazolin and 2 g vancomycin to 821 patients receiving only preoperative cefazolin found a decrease in infection rates from 2.6% in the control group to 0.2% in the treatment group ($p < 0.0001$).[27] In that study, there were no complications due to vancomycin use, and the long-term outcome differences between the treatment and control groups were not significant. Additionally, a cost-benefit analysis of adjuvant vancomycin administration found reduced infection rates from 13% (7 of 54) to 0% (0 of 52) and cost savings of $438,165 per 100 posterior spinal fusions.[14] Thus, the authors of that study concluded that the small upfront cost of intraoperative vancomycin application offsets the deleterious financial and health outcomes affiliated with postoperative infection. The benefit of intraoperative vancomycin has not been universal, however, as demonstrated by a recent prospective study of 907 patients, which showed no difference in infection rate between the treatment (1.61%) and control (1.68%) groups.[29] The authors of that study concluded that when infection rates are low, there is no benefit to vancomycin prophylaxis. The cost effectiveness of vancomycin powder in preventing infections after specifically posterior cervical surgeries remains to be evaluated, and a follow-up study comparing the cost and QOL outcomes associated with intraoperative vancomycin use will help clarify this issue. Additionally, the universal use of vancomycin may contribute to the growing resistance of pathogens associated with hospital-acquired infections, which must be factored into the decision-making process.

The conclusions derived from this study are limited by several factors. This was a retrospective analysis with a relatively short follow-up time. One-year follow-up is the standard of care at our institution, and accordingly, completed PRO questionnaires declined to less than 50% after that time. Prospective investigations using a larger cohort and longer postoperative follow-up times of 2 years or longer may yield a more complete assessment of patient outcomes after DCF. Additionally, for the cost analysis, we used the Medicare reimbursement model to approximate costs. This model does not measure the true cost to the hospital or the patient and can serve as an estimate only. It is, however, more generalizable to the other studies in the literature and to national costs. Despite these limitations, our data analysis followed methodologies identified in other primary cost and QOL studies, giving us confidence in the validity of our findings.[1,20,31,32] Given the findings of this study, patients should be consulted during the consent process about the clinical and financial ramifications of postoperative infection.

Conclusions

This is the first paper to characterize the clinical and financial impacts of dorsal cervical infections. Deep wound infections following DCFs dramatically increase the cost of care while not significantly affecting the long-term postoperative quality of life. The substantial cost increase imposes a significant burden on patients and the health care system, which may warrant investigation into alternative prophylactic methods to reduce the rate of deep postoperative wound infections. Further, surgeons may preoperatively counsel their patients as to the expected outcome should a postoperative infection arise. Additional prospective studies, with larger sample sizes and longer follow-up time, are warranted to better understand the cost and QOL implications of complications following DCF.

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References

1. Alvin MD, Lubelski D, Abdullah KG, Whitmore RG, Benzel EC, Mroz TE: Cost-utility analysis of anterior cervical discectomy and fusion with plating (ACDFP) vs posterior cervical foraminotomy (PCF) for patients with single-level cervical radiculopathy. **Spine (Phila Pa 1976) 13 Suppl:**S120–S121, 2013
2. Beiner JM, Grauer J, Kwon BK, Vaccaro AR: Postoperative wound infections of the spine. **Neurosurg Focus 15(3):**E14, 2003
3. Campbell PG, Yadla S, Malone J, Zussman B, Maltenfort MG, Sharan AD, et al: Early complications related to approach in cervical spine surgery: single-center prospective study. **World Neurosurg 74:**363–368, 2010
4. Campbell PG, Yadla S, Nasser R, Malone J, Maltenfort MG,

Ratliff JK: Patient comorbidity score predicting the incidence of perioperative complications: assessing the impact of comorbidities on complications in spine surgery. **J Neurosurg Spine 16:**37–43, 2012
5. Center for Medicare & Medicaid Services: **Physician Fee Schedule.** (http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/PhysicianFeeSched/index.html) [Accessed November 23, 2014]
6. Chaudhary SB, Vives MJ, Basra SK, Reiter MF: Postoperative spinal wound infections and postprocedural diskitis. **J Spinal Cord Med 30:**441–451, 2007
7. Che W, Li RY, Dong J: Progress in diagnosis and treatment of cervical postoperative infection. **Orthop Surg 3:**152–157, 2011
8. Denaro L, Longo UG, Denaro V: Infections of the cervical spine, in Denaro L, Denaro V (eds): **Pitfalls in Cervical Spine Surgery: Avoidance and Management of Complications.** Berlin: Springer-Verlag, 2010, pp 193–202
9. **DRG Expert: A Comprehensive Guidebook to the DRG Classification System, ed 28.** Eden Prairie, MN: OptumInsight, 2012
10. EuroQol Group: EuroQol—a new facility for the measurement of health-related quality of life. **Health Policy 16:**199–208, 1990
11. Falavigna A, Righesso O, Traynelis VC, Teles AR, da Silva PG: Effect of deep wound infection following lumbar arthrodesis for degenerative disc disease on long-term outcome: a prospective study. Clinical article. **J Neurosurg Spine 15:**399–403, 2011
12. Fang A, Hu SS, Endres N, Bradford DS: Risk factors for infection after spinal surgery. **Spine (Phila Pa 1976) 30:**1460–1465, 2005
13. Freynhagen R, Baron R, Gockel U, Tölle TR: painDETECT: a new screening questionnaire to identify neuropathic components in patients with back pain. **Curr Med Res Opin 22:**1911–1920, 2006
14. Godil SS, Parker SL, O'Neill KR, Devin CJ, McGirt MJ: Comparative effectiveness and cost-benefit analysis of local application of vancomycin powder in posterior spinal fusion for spine trauma. Clinical article. **J Neurosurg Spine 19:**331–335, 2013
15. Hong HS, Chang MC, Liu CL, Chen TH: Is aggressive surgery necessary for acute postoperative deep spinal wound infection? **Spine (Phila Pa 1976) 33:**2473–2478, 2008
16. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG: CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. **Am J Infect Control 20:**271–274, 1992
17. Kasimatis GB, Panagiotopoulos E, Gliatis J, Tyllianakis M, Zouboulis P, Lambiris E: Complications of anterior surgery in cervical spine trauma: an overview. **Clin Neurol Neurosurg 111:**18–27, 2009
18. Kroenke K, Spitzer RL, Williams JB: The PHQ-9: validity of a brief depression severity measure. **J Gen Intern Med 16:**606–613, 2001
19. Massie JB, Heller JG, Abitbol JJ, McPherson D, Garfin SR: Postoperative posterior spinal wound infections. **Clin Orthop Relat Res (284):**99–108, 1992
20. McGirt MJ, Parker SL, Lerner J, Engelhart L, Knight T, Wang MY: Comparative analysis of perioperative surgical site infection after minimally invasive versus open posterior/transforaminal lumbar interbody fusion: analysis of hospital billing and discharge data from 5170 patients. **J Neurosurg Spine 14:**771–778, 2011
21. Olsen MA, Mayfield J, Lauryssen C, Polish LB, Jones M, Vest J, et al: Risk factors for surgical site infection in spinal surgery. **J Neurosurg 98 (2 Suppl):**149–155, 2003
22. Parker SL, Godil SS, Shau DN, Mendenhall SK, McGirt MJ: Assessment of the minimum clinically important difference in pain, disability, and quality of life after anterior cervical discectomy and fusion. Clinical article. **J Neurosurg Spine 18:**154–160, 2013
23. Petilon JM, Glassman SD, Dimar JR, Carreon LY: Clinical outcomes after lumbar fusion complicated by deep wound infection: a case-control study. **Spine (Phila Pa 1976) 37:**1370–1374, 2012
24. Pull ter Gunne AF, Cohen DB: Incidence, prevalence, and analysis of risk factors for surgical site infection following adult spinal surgery. **Spine (Phila Pa 1976) 34:**1422–1428, 2009
25. **Red Book: Pharmacy's Fundamental Reference™. 2007 Edition.** Montvale, NJ: Thomson Healthcare, 2007
26. Rehman A, Rehman AU, Rehman TU, Freeman C: Removing outer gloves as a method to reduce spinal surgery infection. **J Spinal Disord Tech** [epub ahead of print], 2013
27. Sweet FA, Roh M, Sliva C: Intrawound application of vancomycin for prophylaxis in instrumented thoracolumbar fusions: efficacy, drug levels, and patient outcomes. **Spine (Phila Pa 1976) 36:**2084–2088, 2011
28. Tharin S, Mayer E, Krishnaney A: Lumbar microdiscectomy and lumbar decompression improve functional outcomes and depression scores. **Evid Based Spine Care J 3:**65–66, 2012
29. Tubaki VR, Rajasekaran S, Shetty AP: Effects of using intravenous antibiotic only versus local intrawound vancomycin antibiotic powder application in addition to intravenous antibiotics on postoperative infection in spine surgery in 907 patients. **Spine (Phila Pa 1976) 38:**2149–2155, 2013
30. Weinstein MA, McCabe JP, Cammisa FP Jr: Postoperative spinal wound infection: a review of 2,391 consecutive index procedures. **J Spinal Disord 13:**422–426, 2000
31. Whitmore RG, Schwartz JS, Simmons S, Stein SC, Ghogawala Z: Performing a cost analysis in spine outcomes research: comparing ventral and dorsal approaches for cervical spondylotic myelopathy. **Neurosurgery 70:**860–867, 2012
32. Whitmore RG, Stephen J, Stein SC, Campbell PG, Yadla S, Harrop JS, et al: Patient comorbidities and complications after spinal surgery: a societal-based cost analysis. **Spine (Phila Pa 1976) 37:**1065–1071, 2012
33. Xing D, Ma JX, Ma XL, Song DH, Wang J, Chen Y, et al: A methodological, systematic review of evidence-based independent risk factors for surgical site infections after spinal surgery. **Eur Spine J 22:**605–615, 2013
34. Zeidman SM, Ducker TB, Raycroft J: Trends and complications in cervical spine surgery: 1989-1993. **J Spinal Disord 10:**523–526, 1997

Author Contributions

Conception and design: Mroz, Kuhns, Lubelski, Taub, Benzel. Acquisition of data: Kuhns, Lubelski. Analysis and interpretation of data: Kuhns, Lubelski, Alvin. Drafting the article: Kuhns, Lubelski, Alvin. Critically revising the article: Mroz, Kuhns, Lubelski, Alvin, McGirt, Benzel. Reviewed submitted version of manuscript: Mroz, Kuhns, Lubelski, Alvin, McGirt, Benzel. Statistical analysis: Kuhns, Lubelski, Alvin. Study supervision: Mroz, Benzel.

Supplemental Information

Previous Presentation

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