Economic analysis of 90-day return to the emergency room and readmission after elective lumbar spine surgery: a single-center analysis of 5444 patients

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OBJECTIVE In the future, payers may not cover unplanned 90-day emergency room (ER) visits or readmissions after elective lumbar spine surgery. Prior studies using large administrative databases lack granularity and/or use a proxy for actual cost. The purpose of this study was to identify risk factors and subsequent costs associated with 90-day ER visits and readmissions after elective lumbar spine surgery.

METHODS A prospective, multisurgeon, single-center electronic medical record was queried for elective lumbar spine fusion surgeries from 2013 to 2017. Predictive models were created for 90-day ER visits and readmissions.

RESULTS Of 5444 patients, 729 (13%) returned to the ER, most often for pain ($n = 213$, 29%). Predictors of an ER visit were prior ER visit (OR 2.5), underserved zip code (OR 1.4), and number of chronic medical conditions (OR 1.4). In total, 421 (8%) patients were readmitted, most frequently for wound infection ($n = 123$, 2%), exacerbation of chronic obstructive pulmonary disease ($n = 24$, 0.4%), and sepsis ($n = 23$, 0.4%). Predictors for readmission were prior ER visit (OR 1.96), multiple chronic conditions (OR 1.69), obesity (nonobese, OR 0.49), race (African American, OR 1.43), admission status (ER admission, OR 2.29), and elevated hemoglobin A1c (OR 1.80). The mean direct hospital cost for an ER visit was \$1971, with 75% of visits costing less than \$1890, and the average readmission cost was \$7347, with 75% of readmissions costing less than \$8820. Over the 5-year study period, the cost to the institution for 90-day return ER visits was \$5.1 million.

CONCLUSIONS Risk factors for 90-day ER visit and readmission after elective lumbar spine surgery include medical comorbidities and socioeconomic factors. Proper patient counseling, appropriate postoperative pain management, and optimization of modifiable risk factors prior to surgery are areas to focus future efforts to lower 90-day ER visits and readmissions and reduce healthcare costs.

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KEYWORDS lumbar spine surgery; readmission; emergency department; cost; Centers for Medicare and Medicaid Services; CMS

THE Centers for Medicare and Medicaid Services (CMS) has made decreasing hospital readmissions within the 30- to 90-day postoperative period a priority to curb rapidly increasing healthcare costs. From 2003 to 2004, 20% of Medicare patients were readmitted within 30 days of their hospitalization and 34% within 90 days.¹ Around half (51.5%) of the patients who were discharged after elective surgical procedures were readmitted or deceased 1 year after discharge, with total costs to Medicare estimated to be \$17.4 billion in 2004. Up to 90% of these visits were thought to be avoidable.¹ Starting in 2010, the Hospital Readmissions Reductions Program, a

product of the Affordable Care Act, has penalized hospitals for certain unplanned readmissions within 30 days of discharge.²

Recent research aimed at identifying risk factors for early readmission after elective spine surgery has used national databases, including the National Readmission Database (NRD)^{3,4} and the Quality Outcomes Database (QOD).^{5,6} While these data sets contain a large amount of information, they may lack granularity compared with single-center data sets, limiting the conclusions that can be drawn from these studies. The purpose of this study was to identify risk factors for return to the emergency room

ABBREVIATIONS ASA = American Society of Anesthesiologists; CMS = Centers for Medicare and Medicaid Services; COPD = chronic obstructive pulmonary disease; DRG = Diagnosis-Related Group; ER = emergency room; HCUP = Healthcare Cost and Utilization Project; LOS = length of stay; NRD = National Readmission Database; NSQIP = National Surgical Quality Improvement Program; QOD = Quality Outcomes Database; SID = State Inpatient Databases; VAS = visual analog scale.

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TABLE 1. DRG codes utilized for cost analysis

DRG Code	Definition
456	Spinal fusion except cervical w/ spinal curvature or malignancy or infection or extensive fusion w/ MCC
457	Spinal fusion except cervical w/ spinal curvature or malignancy or infection or extensive fusion w/ CC
458	Spinal fusion except cervical w/ spinal curvature or malignancy or infection or extensive fusion w/o MCC or CC
459	Spinal fusion except cervical w/ MCC
460	Spinal fusion except cervical w/o MCC

CC = complication or comorbidity; MCC = major complication or comorbidity.
Source: www.cms.gov.

(ER) and readmission 90 days after elective lumbar spine surgery. These risk factors could then potentially be mitigated to reduce costs and facilitate improved patient care.

Methods

Institutional review board approval was obtained for this study. The electronic medical record from a multisurgeon single center was queried for patients 18 years of age and older who underwent elective lumbar spine surgery from 2013 to 2017 with Diagnosis-Related Group (DRG) codes 456–460 (Table 1). Cases were limited to these DRG codes to exclude simple discectomies and decompressions as well as long fusion surgeries. All procedures were performed by eight fellowship-trained orthopedic spine surgeons. Obvious variations in operative techniques exist, but all surgeries were either open or mini-open with no percutaneous or tubular techniques. Demographic and hospital admission data for the index surgery were obtained. The incidence of all patients needing ER visits or hospital readmissions within 90 days of their surgery date were then identified. The center where the study was performed had a dedicated triage nurse available during typical business hours and encouraged office utilization whenever possible with “same day” or “urgent” office spots available on a daily basis. Actual hospital cost data (not Medicare allowable rates or charges) were obtained from the institution relative to the DRG codes utilized for the postsurgery encounters.

Statistical Analysis

All statistical analyses were performed using SPSS version 25.0 (IBM Corp.). Predictive modeling was performed to evaluate associations with 90-day ER visit and readmissions. A univariate analysis was done initially to identify factors to include in the model. Only factors with a *p* value < 0.20 were included in the final logistic regression. Factors considered included prior ER visit, zip code, number of chronic medical conditions, ethnicity, hemoglobin A1c ≥ 7.0 , payer, age, pain score as shown on a visual analog scale (VAS), sex, provider status, marital status, and obesity. Chronic medical conditions analyzed included diabetes mellitus, congestive heart failure, chronic obstructive pulmonary disease (COPD), hypertension, and obesity. Zip codes in our region were designated as

TABLE 2. Summary of demographic data

	Value
Age in yrs, mean $\pm$ SD	54.20 $\pm$ 17.12
Sex	
Female	3181 (58.4)
Male	2263 (41.6)
Race/ethnicity	
White	4792 (88.0)
African American	518 (9.5)
Unknown/other	79 (1.5)
Hispanic	38 (0.7)
Asian	9 (0.2)
Marital status	
Married	3010 (55.3)
Single	1326 (24.4)
Divorced/separated	683 (12.5)
Widowed	332 (6.1)
Unknown/other	93 (1.7)
Chronic medical conditions	
0	1821 (33.4)
1	1567 (28.8)
2	1239 (22.8)
3	690 (12.7)
4	106 (1.9)
5	22 (0.4)
Obese	2192 (40.3)
Insurance status	
Medicaid/Medicare	3247 (59.6)
Private	1817 (33.4)
Other	370 (6.8)
Self	11 (0.2)

Values are presented as number (%) of patients unless otherwise indicated.

“underserved” by the government if the residents had a high prevalence of health conditions in combination with a higher than average poverty rate and less access to healthcare. Additionally, cost was calculated as direct, actual hospital costs (not charges or Medicare allowable rates) across all service lines and included all costs for that episode of care. Outpatient costs after the index surgery, ER visit, or readmission were not included. Only variables noted to have a *p* value < 0.20 were included in the final model. Odds ratio (OR) values are given with 95% confidence intervals (CIs).

Results

In total, 5444 consecutive patients (58% female, 42% male) underwent elective lumbar spine surgery at our institution from 2013 to 2017 (Table 2). The top 5 preoperative diagnoses were stenosis (34.0%), spondylosis (18.7%), spondylolisthesis (17.3%), pseudoarthrosis (5.6%), and disc herniation (4.6%). The majority (*n* = 3085, 57%) of patients were sent home with self-care or with home health ser-

TABLE 3. Reasons for ER visit

	No. (%) of Patients
Postop pain	213 (29)
Sciatica/radiculopathy	168 (23)
Trauma	76 (10)
Cardiac	49 (7)
Abdominal pain	20 (3)
Altered mental status	18 (2)
COPD	16 (2)
Urinary tract infection	15 (2)
Headache	15 (2)
Syncope	14 (2)
Cellulitis, leg or arm	12 (2)
Nausea & vomiting	10 (1)
Muscle strain/sprain	17 (2)
Hypertension	10 (1)
Arthritis	10 (1)
Allergic reaction	10 (1)
Deep vein thrombosis	9 (1)
Upper respiratory tract infection	7 (1)
Urinary retention	6 (1)
Stroke	6 (1)
Postop infection	8 (1)
Pneumonia	6 (1)
Opiate withdrawal	4 (1)

vice ($n = 1062$, 20%). The rest were discharged to a skilled nursing facility ($n = 991$, 82%) or a rehabilitation facility ($n = 281$, 5%). In total, 729 (13%) of the cohort returned to the ER within 90 days of surgery; 213 (29%) of these patients returned to the ER for pain-related complaints with or without sciatica ($n = 168$, 23%), and 33 (4.5%) of the patients came back for concerns regarding infections (Table 3). The strongest predictors for a return to the ER within this time period were a prior ER visit (OR 2.5, CI 1.8–3.4, $p < 0.001$), underserved zip code (OR 1.4, CI 1.2–1.7, $p = 0.000$), and higher number of chronic medical conditions (OR 1.4, CI 1.1–1.7, $p = 0.002$) (Table 4). The mean direct hospital cost for an ER visit was \$1971, with 75% of visits costing less than \$1890 (Table 5).

In total, 421 (8%) patients were readmitted within 90 days of surgery. Half of the readmissions were from the ER, 47% were direct admissions from the clinic, and 2% were from other hospitals. The most common reasons for readmission were wound infection (123 cases, 29%), revision of fusion (60 cases, 14%), COPD exacerbation (24 cases, 5.7%), and sepsis (23 cases, 5.4%) (Table 6). The mean length of stay (LOS) after readmission for all patients was 6.1 days (range 1–44 days). For patients who required revision surgery, the average LOS was 7.7 days (range 1–44 days), and for those who required medical management alone, the average LOS was 4.7 days (range 1–36 days). The strongest predictors of readmission were prior ER visit (OR 1.96, CI 1.34–4.00, $p = 0.001$), multiple chronic health conditions (OR 1.69, CI 1.30–2.20, p

TABLE 4. Predictors evaluated for 90-day return to the ER

Predictor	Chi-Square Score	Chi-Square p Value	OR (95% CI)	p Value
Prior ER visit	102.95	<0.0001	2.5 (1.8–3.4)	<0.0001
Underserved zip code	47.40	<0.0001	1.4 (1.2–1.7)	0.0004
Increasing chronic medical conditions	23.15	<0.0001	1.4 (1.1–1.7)	0.002
African American race	19.12	<0.0001	1.6 (1.2–2.0)	0.0002
Elevated hemoglobin A1c	14.08	0.0028	1.5 (1.0–2.1)	0.0458
Payer status	14.25	0.0065	—	—
Patient age	13.93	0.0030	—	—
VAS scores	12.33	0.0151	—	—
Admission status	9.52	0.0231	—	—
Sex	4.78	0.0287	—	—
Provider status	4.29	0.0382	—	—
Marital status	7.14	0.0676	—	—
BMI status	5.49	0.2411	—	—

= 0.000), obesity (nonobese, OR 0.49, CI 0.35–0.70, $p < 0.000$), African American race (OR 1.43, CI 1.04–1.95, $p = 0.026$), admission status from the ER (OR 2.29, CI 1.31–4.00, $p = 0.004$), and elevated hemoglobin A1c (OR 1.80, CI 1.16–2.65, $p = 0.007$) (Table 7).

The mean direct hospital cost for an ER visit was \$1971, with 75% of visits costing less than \$1890, and the average readmission cost was \$7347, with 75% of readmissions costing less than \$8820 (Table 5). Combined, the estimated cost to the hospital was \$5.1 million over the 5-year study period (Fig. 1).

Discussion

In this single-center cohort of patients, our results show similar rates of return to the ER (13%) and readmission (8%), consistent with results reported in previously published literature. This study links socioeconomic factors, such as ethnicity and residing in an underserved zip code, to unplanned ER visit and hospital readmission in the 90-day postoperative period. The strongest predictor for both

TABLE 5. Direct hospital costs

Percentile	ER Visit			90-Day Readmission
	30-Day	90-Day	All	
25th	256.03	280.86	266.03	5570.21
50th	544.12	694.19	690.19	7059.42
75th	2148.30	1490.23	1890.09	8820.61
95th	8496.15	12104.87	8499.15	12950.41
100th	11021.13	13453.13	13453.13	14857.82

Values are in US dollars.

TABLE 6. Reasons for readmission

	No. (%) of Patients
Incision & drainage	123 (29)
Revision fusion	60 (14)
Line insertion	27 (6)
COPD	24 (6)
Sepsis	23 (5)
Implant removal/revision	19 (5)
Repair of CSF leak	4 (1)
Cardiac stent	3 (1)
Revision decompression	3 (1)
Cholecystectomy	2 (0)
Secondary wound closure	2 (0)

return to the ER and readmission was an ER visit within the previous 6 months. A subset of patients continue to use the ER as their primary means of obtaining healthcare, even though 94% of the patients in the cohort indicated that they had a primary care physician. It stands to reason that these patients would continue to use the ER in the postoperative period as well, as shown in our series. ER visits were also more common in patients from zip codes with poor socioeconomic factors and areas where an outpatient facility associated with our institution was not located within a 10-mile radius of the patient homes. In addition, general signs of poor overall health, such as obesity, elevated hemoglobin A1c, and multiple chronic medical conditions, continue to be predictors for hospital admission. This study suggests that local access to care and established patterns of ER use greatly contribute to patients returning to the hospital in the perioperative period.

Recent literature primarily consists of large, tertiary referral center case series and database queries (Table 8). Adogwa et al. looked at 1400 elective spine cases, identifying a 9.4% 30-day readmission rate, most commonly for infection and pain.⁷ In 500 elective spine surgery patients, Elsamadicy et al. found that a preoperative BMI of ≥ 30 kg/m² was associated with a twofold increase in the 30-

FIG. 1. Number of patients graphed against the costs of each 30-day (black) and 90-day (red) ER visit and 90-day readmission (blue). Figure is available in color online only.

day readmission rate.⁸ Martin et al., in over 1300 spine surgery patients, found that an 11.8% 30-day readmission rate was associated with African American race and LOS > 7 days.⁹ In approximately 37,000 patients, Jain et al. found a 12.8% 30-day return-to-ER rate, most commonly for cardiorespiratory complaints (30.5%) and pain (47.7%).¹⁰

McGirt et al. identified nearly 7000 patients who underwent lumbar spine surgery in the QOD and found a 90-day readmission rate of 6.8%. Readmission, increased LOS, and discharge to a rehabilitation setting were associated with age ≥ 70 years, American Society of Anesthesiologists (ASA) class > III, Oswestry Disability Index score ≥ 70 , diabetes, Medicare/Medicaid, nonindependent ambulation, and fusion.⁵ Wadhwa et al. identified 9800 patients in the QOD and found a 6.3% 90-day readmission rate, associated with higher ASA class, depression, and government insurance.⁶ Rubel et al. utilized the NRD to identify nearly 170,000 patients who underwent elective lumbar spine surgery, noting a 2.5% 90-day readmission rate. Anemia, diabetes, surgical wound disruption, acute myocardial infarction at time of index admission, and anterior surgical approach were found to be independent pre-

TABLE 7. Predictors evaluated for 90-day readmission

Predictor	Chi-Square Score	Chi-Square p Value	OR (95% CI)	p Value
Prior ER visit	33.50	<0.0001	2.0 (1.3–2.9)	0.005
Underserved zip code	1.23	0.267		
Increasing chronic medical conditions	51.93	<0.0001	1.7 (1.3–2.2)	<0.0001
African American race	12.27	0.002	1.4 (1.0–2.0)	0.0267
Elevated hemoglobin A1c	11.76	0.008		
Payer status	2.14	0.144		
VAS scores	5.84	0.212		
Admission status	20.16	0.0002	2.3 (1.3–4.0)	0.004
Provider status	2.14	0.144		
Marital status	7.34	0.062		
Obese BMI	20.04	0.0005	0.5 (0.4–0.7)	<0.0001

TABLE 8. Summary of previously published data

Authors & Year	Database	No. of Patients	Readmission Rate	
			30-Day	90-Day
Rubel et al., 2019 ⁴	NRD	169,788	—	2.5%
Elsamadicy et al., 2019 ³	NRD	144,123	5.0%	7.3%
Jain et al., 2019 ¹⁰	"National Insurance Database"	37,559	3.9%	—
Chen et al., 2020 ¹¹	SID HCUP	267,976	7.5%	11.6%
Sivaganesan et al., 2019 ¹²	QOD	33,674	—	6.15%
Cui et al., 2019 ¹⁴	NRD	26,727	5.91%	9.74%
Lee et al., 2019 ¹⁵	—	1248	2.96%	7.53%
McGirt et al., 2017 ⁵	QOD	6921	—	6.8%
Wadhwa et al., 2017 ⁶	QOD	9853	—	6.3%
Adogwa et al., 2017 ⁷	—	1400	9.4%	—
Martin et al., 2017 ⁹	—	1346	11.8%	—
Basques et al., 2017 ¹⁶	NSQIP	1287	—	—
Elsamadicy et al., 2016 ⁸	—	500	8.6%	—
Pugely et al., 2014 ¹³	"Large multicenter clinical registry"	15,668	4.4%	—

dictors.⁴ Elsamadicy et al. queried the NRD and identified over 140,000 patients with an overall 90-day readmission rate of 7.3%. Age, insurance status, COPD, depression, hypertension, diabetes, deficiency anemia, and obesity were all associated with 30-day readmission and the same, except for age and obesity, were associated with 90-day readmission.³ Chen et al. identified over 265,000 lumbar spine surgery patients in the State Inpatient Databases (SID) Healthcare Cost and Utilization Project (HCUP), finding a 7.5% 30-day and an 11.5% 90-day readmission rate, associated with African American race and nonprivate insurance or self-pay, but not median household income.¹¹ Sivaganesan et al.¹² utilized the QOD in an effort to create a predictive model for 90-day readmissions after lumbar surgery. They found a 6.15% readmission rate in over 33,000 patients. Medical readmissions were associated with older patients, males more than females, African Americans compared with Caucasians, higher ASA grades, diabetes, coronary artery disease, higher number of surgical levels, and anterior lumbar spine surgery. Surgical readmissions were associated with higher BMI, higher ASA class, females more than males, and African Americans compared with Caucasians.¹²

Pugely et al. noted a 4.4% 30-day readmission rate in lumbar spine surgery patients, the lowest being after discectomy (3.3%) and the highest after deformity surgery (9.0%). Predictors included age over 80 years, African American race, recent weight loss, COPD, history of cancer, elevated creatinine over 1.2, elevated ASA class, operative time over 4 hours, and LOS greater than 4 days.¹³ Cui et al. utilized the NRD and, out of more than 26,000 posterolateral lumbar fusions, identified a 5.91% readmission rate within 90 days of surgery, over half of which were within the first 30 days.¹⁴ Lee et al. and a group out of South Korea performed a retrospective review over the prior 10 years at their institution, identifying a 3% 30-day and a 7.5% 90-day readmission rate in patients over the age of 70 who underwent degenerative lumbar spine sur-

gery.¹⁵ Basques et al. used the National Surgical Quality Improvement Program (NSQIP) database to identify patients who had undergone revision lumbar spine surgery and found that BMI greater than 25, ASA score greater than 3, insulin-dependent diabetes, and 2 or more levels of lumbar fusion were all associated with 30-day readmission.¹⁶

Overall, our series has similar readmission rates compared with these studies. This study is the first to analyze a large cohort not utilizing an administrative database. The benefit of this is increased granularity, emphasized by our findings of prior ER utilization and zip code status being significant contributors. While the majority of our predictors have been noted in prior literature, these factors are not typically captured in queries of large administrative data sets. The use of an internal data set also allowed us to evaluate the costs of these ER visits and readmissions. This information has not been evaluated in the previous studies already cited above. The distribution of ER visit and readmission costs is as expected, with most ER visits costing less than \$2000 and readmission costing less than \$9000, and a smaller number of patients accounting for the majority of the total cost over the 5-year period. Our study also shows the huge cost savings that can be achieved if factors that lead to ER visits and readmission can be controlled.

There are limitations to our study. Although our hospital system has multiple locations throughout the region and patients are encouraged to come to our facility should they have a problem, there is a percentage of patients who go to another ER or hospital for care within the perioperative period. These patients would be missed in our analysis. Additionally, since the study is a single-center one, there is concern for widespread applicability. Our region could have trends in ER utilization that are unique to our population. This limitation is negated in large administration database studies. Additionally, operative characteristics, postoperative complications, diagnosis code, and dis-

charge disposition after index admission were not assessed as potential risk factors for ER visit or readmission.

Careful patient selection when scheduling patients for elective surgery is critical to obtaining good results. Not only should pathology, imaging, and clinical examination drive decision making, but also preexisting medical conditions and socioeconomic status should play a role in the counseling of risks associated with surgery. Optimizing modifiable risk factors, such as obtaining adequate glucose control in diabetic patients and losing weight in obese patients, could potentially help to reduce readmissions after surgery. Socioeconomic factors, while often not entirely modifiable, can be partially accounted for with preoperative counseling. As pain was the most common reason for an ER visit, patient education on what to expect after surgery and how to manage postoperative pain would help to mitigate an early return to the ER. Written materials could help supplement the discussion in regard to what to expect after surgery. In certain situations, involvement of a social worker can help to identify resources for patients in underserved areas. Although not in the context of spine surgery, several studies have found that just by hiring more social services or case management employees, the return-to-ER rate can be cut nearly in half with reductions in readmissions and cost, especially in frequent ER users.^{17–20} As in our study, previous ER utilization prior to surgery was the strongest risk factor for returning to the ER postoperatively. Therefore, identification of these patients prior to surgery could, in theory, decrease the unnecessary return to the ER and readmissions by addressing these issues during patient counseling. Ideally, a “real-time” center-, surgeon-, and patient-specific model such as this could be utilized to identify high-risk patients and adjust the preoperative counseling session to add more emphasis on appropriate postoperative management. Finally, after-hours contact information with resources for patients to utilize would certainly help with any questions and potentially avoid unnecessary trips to the ER.

Lastly, the Patient Protection and Affordable Care Act (PPACA) includes alternative payment models that shift away from fee-for-service reimbursement and provide incentives to improve value. The Center for Medicare and Medicaid Innovation (CMMI) is piloting episode-based bundled payments through its Bundled Payment for Care Improvement (BPCI) program, which provides a predetermined reimbursement that encompasses all services related to target diagnosis or procedures over a predefined time frame. To be successful, at least from a hospital perspective, the hospital must contain costs below the bundled payment threshold. Within this type of bundled payment initiative, the hospital would assume the cost associated with returning to the ER or readmission. These models are more common in joint arthroplasty and rare in spine care. Although currently institutions are reimbursed for a return ER visit or readmission, in a bundled payment model, the institution would have lost millions on return-to-ER and readmission visits, respectively. Even though we get reimbursed currently, the mean ER reimbursement for our cohort is below more common ER visit reimbursements, indicating a waste of ER resources and adding to longer ER wait times. The mean reimbursement for our cohort

was 16% lower per ER visit to our institution over the study time frame compared with a traditional ER patient. Additionally, if the cumulative readmissions for the year are too high among CMS patients, an institution could incur a penalty reduction in payments for the following year. Private payers tend to take the lead from guidelines established by CMS, and while a particular insurer was not associated with ER visits or readmissions in our study, it stands to reason that reimbursements from all payers could be affected going into the future.

Conclusions

Risk factors for an unplanned trip to the ER and hospital readmission in the immediate postoperative period after elective lumbar spine surgery include a prior ER visit, residing in an underserved zip code, African American race, obesity, elevated hemoglobin A1c, and chronic medical comorbidities, most commonly pain complaints. These postoperative encounters represent a significant healthcare cost. Proper patient counseling, appropriate postoperative pain management, and optimization of modifiable risk factors prior to surgery are areas to focus future efforts to lower the rates of 90-day ER visits and readmissions and reduce healthcare costs.

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Disclosures

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Author Contributions

Conception and design: Carreon, Djurasovic, Glassman, Khalil, Kannapel, Gum. Acquisition of data: Khalil, Kannapel, Gum. Analysis and interpretation of data: Wiley, Khalil. Drafting the article: Wiley. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Carreon. Statistical analysis: Khalil. Administrative/technical/material support: Carreon, Djurasovic, Glassman, Kannapel, Gum. Study supervision: Carreon, Djurasovic, Glassman, Kannapel, Gum.

Supplemental Information

Previous Presentations

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