An institutional intervention to modify opioid prescribing practices after lumbar spine surgery

Francis Lovecchio, MD,1 Jeffrey G. Stepan, MD, MSc,1 Ajay Premkumar, MD, MPH,1 Michael E. Steinhaus, MD,1 Maria Sava, BA,1 Peter Derman, MD, MBA,2 Han Jo Kim, MD,1 and Todd Albert, MD1

1Hospital for Special Surgery, New York, New York; and 2Midwest Orthopaedics at Rush, Chicago, Illinois

OBJECTIVE Patients with lumbar spine pathology are at high risk for opioid misuse. Standardizing prescribing practices through an institutional intervention may reduce the overprescribing of opiates, leading to a decrease in the risk for opioid misuse and the number of pills available for diversion. Without quantitative data on the “minimum necessary quantity” of opioids appropriate for postdischarge prescriptions, the optimal method for changing existing prescribing practices is unknown. The purpose of this study was to determine whether mandatory provider education and prescribing guidelines could modify prescriber behavior and lead to a decreased amount of opioids prescribed at hospital discharge following lumbar spine surgery.

METHODS Qualified staff were required to attend a mandatory educational conference, and a consensus method among the spine service was used to publish qualitative prescribing guidelines. Prescription data for 2479 patients who had undergone lumbar spine surgery were captured and compared based on the timing of surgery. The preintervention group consisted of 1177 patients who had undergone spine surgery in the period before prescriber education and guidelines (March 1, 2016–November 1, 2016). The postintervention group consisted of 1302 patients who had undergone spine surgery after the dissemination of the guidelines (February 1, 2017–October 1, 2017). Surgeries were classified as decompression or fusion procedures. Patients who had undergone surgeries for infection and patients on long-acting opioids were excluded.

RESULTS For all lumbar spine surgeries (decompression and fusion), the mean amount of opioids prescribed at discharge was lower after the educational program and distribution of prescribing guidelines (629 ± 294 oral morphine equivalent [OME] preintervention vs 490 ± 245 OME postintervention, p < 0.001). The mean number of prescribed pills also decreased (81 ± 26 vs 66 ± 22, p < 0.001). Prescriptions for 81 or more tablets dropped from 65.5% to 25.5%. Tramadol was prescribed more frequently after prescriber education (9.9% vs 18.6%, p < 0.001). Refill rates within 6 weeks were higher after the institutional intervention (7.6% vs 12.4%, p < 0.07).

CONCLUSIONS Qualitative guidelines and prescriber education are effective in reducing the amount of opioids prescribed at discharge and encouraging the use of weaker opioids. Coupling provider education with prescribing guidelines is likely synergistic in achieving larger reductions. The sustainability of these changes is yet to be determined.

https://thejns.org/doi/abs/10.3171/2018.8.SPINE18386

KEYWORDS opioid prescriptions; lumbar spine surgery; prescribing guidelines

Spine surgeons are on the front lines of the current opioid epidemic, treating patients at particularly high risk for opioid use disorders. In an evaluation of pain intensity after 179 surgical procedures across multiple specialties, patients who had undergone spine surgery reported the highest pain scores.11 In those who use prescription opioids long term, spinal conditions are the most common diagnoses for the first prescription,29 and more than half of the patients who use opioids have chronic back pain.6

Unfortunately, there is a paucity of data on the quantity of opioids to prescribe after spine surgery, leaving provid-
ers trapped between the need to alleviate suffering and a lack of evidence on what constitutes an “appropriate minimum quantity” for a postdischarge prescription. This conflict has contributed to overprescribing, often leaving patients with leftover narcotic pills after surgery. The push to reduce opioid prescriptions is further supported by the lack of an association between increased opioid dosage and pain relief, multiple side effects (including death), an association with postoperative complications, and the legal ramifications of careless prescribing.

The American Academy of Orthopaedic Surgeons has called for the standardization of opioid prescribing practices in an attempt to decrease overprescribing and the number of pills available for diversion. Institutional interventions have been shown to reduce the quantity and variance in opioid prescriptions after hand and general surgery. Prescriber education on the risks of opioid use and a written guideline on institutional practices form the two common tenets of such interventions. Currently, the lack of knowledge regarding average postoperative opioid consumption following lumbar spine surgery inhibits the ability to form quantitative evidence-based guidelines. Arbitrarily assigning a number of pills to each surgery without high-quality data on opioid consumption patterns could run the risk of widespread uncontrolled pain or an abundance of unused pills. Thus, qualitative guidelines may prove effective in reducing the number of opioids prescribed at discharge. The purpose of the present study was to investigate the impact of a provider education program and qualitative guidelines on opioid prescriber behaviors after lumbar spine surgery. We hypothesized that our institutional intervention would lead prescribers to decrease the amount of opioids given after lumbar spine surgery.

Development of Prescribing Guidelines

Each orthopedic subspecialty service was tasked with the creation of its own prescribing guidelines, which were reviewed by the opioid task force. An initial literature review revealed a dearth of studies directly measuring the amount of postdischarge opioids consumed after spine surgery. Therefore, a consensus-based method was utilized to establish guidelines. This method consists of gathering experts in a particular field and allowing them to convene in a structured environment, using their combined clinical experiences and expertise along with the best available evidence to formulate a solution to a challenging clinical issue.

A multidisciplinary committee of pain medicine physicians, anesthesiologists, nurse managers, and spine surgeons was charged with developing a set of guidelines for opioid prescribing after spine surgery (Fig. 1). A literature review was performed for the committee to cross-reference with their clinical experience. Given the lack of evidence on the quantity of opioids consumed upon hospital discharge after spine surgery, the committee decided on a qualitative approach to the prescribing guidelines, relying on a patient’s inpatient or postanesthesia care unit (PACU) opioid consumption to inform the outpatient prescription. At our institution, the most common opioids prescribed at discharge included tramadol, oxycodone/acetaminophen, hydrocodone/acetaminophen, and hydromorphone. The committee believed that oxycodone/acetaminophen 5–325 mg, hydrocodone/acetaminophen 5–325 mg, tramadol 50 mg, and hydromorphone 2 mg provided clinically comparable relief and were appropriate for postoperative discharge prescriptions. In cases in which a combined pill would lead to the ingestion of dangerous amounts of acetaminophen, the two components were broken up into separate prescriptions. The opioid prescription was emphasized as only one part of a multimodal approach to postoperative pain control. Certain factors were believed to be especially pertinent to patients undergoing spine surgery, such as minimizing the concomitant use of benzodiazepines and muscle relaxants, avoiding long-acting opioids, and using only one type of opioid. Lastly, given the high prevalence of opioid use in patients with lumbar spine pathology, the guidelines make special note that they are to apply to opioid-naïve patients only. Guidelines were disseminated for use on the hospital website, in patient care areas, and in the resident and physician assistant workrooms starting in February 2017.

Determining the Impact of Education and Guidelines

All opioid medications prescribed at discharge were extracted from the hospital-wide EMR. We included all opioid prescriptions written at discharge following lumbar spine surgery in the 8 months before prescriber education (March 1, 2016–November 1, 2016) and in the 8 months following education (March 1, 2017–November 1, 2017). The number, type, and amount of opioid prescriptions in the first 8 months before and after prescriber education were reviewed to compare the 8-month periods before and after the institutional intervention.

Methods

Overview

At an orthopedic specialty hospital, all employees eligible to prescribe opioid medications were required to attend a mandatory educational program in November 2016. Over the next 4 months, qualitative prescribing guidelines were conceived by the spine surgery service and were disseminated in February 2017. After institutional review board approval, prescribing data from the hospital’s electronic medical record (EMR) were reviewed to compare the number, type, and amount of opioid prescriptions in the 8-month periods before and after the institutional intervention.

Prescriber Education

At our institution, an opioid task force was created that consisted of orthopedic surgeons, anesthesiologists, pain specialists, hospital administrators, legal counsel, and house staff representatives. The task force created a 1-hour educational lecture addressing the scope and origin of the opioid epidemic, the role of orthopedic prescribers, multimodal analgesia, the statewide controlled substance registry, and the state laws mandating electronic prescribing of opioids. All prescribers completed the program in either a live lecture or web series format.
after dissemination of the guidelines (February 1, 2017–October 1, 2017). Procedures were categorized as decompression only (decompression of neural elements without placement of hardware) or fusion (placement of instrumentation, including pedicle screws, dynamic stabilization, or interbody devices). Because of the way procedures are coded in our EMR, only the primary procedure could be recorded, and other specifics, such as the use of combined approaches, osteotomies, or number of fusion levels, could not be included. Incision and drainage and hematoma evacuations were excluded from the analysis. Prescriptions written by chronic-pain providers, long-acting opioids, or atypical opioids not addressed by the prescribing guidelines were excluded from the analysis. prescriptions written by chronic-pain providers, long-acting opioids, or atypical opioids not addressed by the prescribing guidelines were excluded from the analysis as these represented medications written for patients whose postoperative pain relief regimens were managed by pain specialist teams and thus not covered by the prescribing guidelines.

Opioid prescriptions given prior to mandatory education and the distribution of guidelines belonged to the “preintervention,” or control, group (March 1, 2016–November 1, 2016), and prescriptions given after the dissemination of guidelines were categorized in the “postintervention” group (February 1, 2017–October 1, 2017). The number of pills and the type of opioids prescribed were recorded for each prescription. To facilitate comparisons of the amount of opioids prescribed, all prescriptions were converted into the oral morphine equivalent (OME) by multiplying the number of pills by the conversion factor. The following conversion factors were used: hydrocodone 5 mg = 5 OME, oxycodone 5 mg = 7.5 OME, codeine 30 mg = 4.5 OME, hydromorphone 2 mg = 8 OME, tramadol 50 mg = 5 OME, morphine 1 mg = 1 OME. To evaluate outpatient refill rates before and after the intervention, New York State Prescription Monitoring Program data were retrieved from the charts of a random sample of 250 patients from each cohort (500 patients total). These data were reviewed to determine refill rates within 6 weeks after surgery.

**Statistical Analysis**

Number of pills, OME, body mass index, and age were compared between the two groups by using Mann-Whitney U-tests with Bonferroni corrections of type I error thresholds to adjust for multiple comparisons. Categorical variables (rates of opioid medication classes prescribed and rates of prescriptions in defined pill ranges) before and after guidelines were compared using Pearson’s chi-square test. To estimate the decrease in pills prescribed after prescriber education and guidelines dissemination, we first extrapolated the average annual number of each type of procedure performed based on 8 months of post-guidelines data. To calculate the hypothetical “number of pills saved” by the intervention, we used the following formula: pills saved = (average procedures per year post-guidelines) × (mean pre-education pills – mean post-guidelines pills). All statistical analyses were performed using SPSS version 22 (IBM Corp.).
Results

Demographics and procedure types were similar in the pre- and postintervention cohorts (Table 1). For all procedures (decompression and fusion), there was a significant decrease in the OME and number of tablets prescribed in the postintervention cohort (Table 2). This pattern was repeated in the decompression and fusion groups. The decompression group had the largest drop in both the OME and the number of pills prescribed. Furthermore, the standard deviation of the number of pills and OME prescribed also decreased in all groups after guidelines were implemented. The median number of pills similarly decreased for each group. For all procedures, a median of 90 (IQR 60–100) was prescribed in the preintervention cohort and 70 (IQR 56–84) in the postintervention cohort (p < 0.001). Similarly, after the guidelines, there were decreases in the median number of pills prescribed after decompression only (90, IQR 70–90 vs 60, IQR 50–80, p < 0.001) and after fusion procedures (90, IQR 60–100 vs 70, IQR 60–84, p < 0.001). These decreases theoretically corresponded with a large number of pills saved. For all procedures, we estimated that 26,040 narcotic pills were saved; for decompression, 19,584 pills; and for fusion, 6480 pills.

Figures 2–4 demonstrate that for all groups there was a significant shift in prescriber behavior toward writing prescriptions for a lower number of pills. In the period before the intervention, 65.5% of prescriptions were written for 81 or more pills, a rate that dropped to 25.5% after education and guidelines. Prescriptions for quantities in the 41–60 and 21–40 ranges became much more common. The most notable shifts occurred in the decompression group, while those in the fusion group were more modest.

Table 3 demonstrates that prescribers made only modest changes to the types of opioids prescribed after the interventions. This behavior change was mostly manifested by an increase in the rate of tramadol prescriptions written after the interventions (9.9% preintervention vs 18.7%, p < 0.001). Decompression surgeries showed the greatest changes. For fusion surgeries, there was a decrease in the proportion of prescriptions written for hydromorphone (19.4% preintervention vs 15.6% postintervention, p = 0.146), but this decrease was not significant.

Outpatient refill rates did not differ but trended

| TABLE 1. Demographic and procedural characteristics of patient sample |
|------------------|------------------|------------------|------------------|
| Variable         | Preintervention Group | Postintervention Group | p Value |
| No. of patients  | 1177              | 1302              | 0.133     |
| Sex              |                   |                   |           |
| Male             | 673 (57.2%)       | 706 (54.2%)       |           |
| Female           | 504 (42.8%)       | 596 (45.8%)       |           |
| Age in yrs       | 57 ± 16           | 58 ± 16           | 0.335     |
| BMI (kg/m²)      | 28.4 ± 5.7        | 28.2 ± 5.6        | 0.354     |
| ASA classification |                 |                   | 0.943     |
| I                | 109 (9.3%)        | 118 (9.1%)        |           |
| II               | 866 (73.6%)       | 970 (74.5%)       |           |
| III              | 178 (15.1%)       | 184 (14.1%)       |           |
| Not recorded     | 24 (2.0%)         | 30 (2.3%)         |           |
| Primary procedure |                   |                   | 0.337     |
| Laminectomy/ decompression | 492 (41.8%) | 544 (41.8%) |           |
| Microdiscectomy  | 266 (22.6%)       | 263 (20.2%)       |           |
| Ant interbody fusion | 75 (6.4%)  | 99 (7.6%)         |           |
| Direct lat interbody fusion | 99 (8.4%)  | 103 (7.9%)        |           |
| Pst fusion w/ or w/o interbody | 245 (20.8%) | 293 (22.5%)       |           |

Ant = anterior; ASA = American Society of Anesthesiologists; pst = posterior. Data reported as no. (%) or mean ± standard deviation. A type I error of p < 0.05 was considered statistically significant.

| TABLE 2. Changes in opioid prescriptions after prescriber education and guidelines |
|------------------|------------------|------------------|------------------|
| Variable         | Total         | Decompression | Fusion         |
|                  | No. of Patients | OME ± Tablets | No. of Patients | OME ± Tablets | No. of Patients | OME ± Tablets |
| Preintervention group | 1177    | 629 ± 294       | 81 ± 26         | 755          | 604 ± 241       | 81 ± 23         |
| Postintervention group | 1302    | 490 ± 245       | 66 ± 22         | 816          | 462 ± 230       | 63 ± 22         |
| p value          | <0.001       | <0.001          | <0.001          | <0.001       | 0.001          | <0.001          |

Data are reported as the means ± standard deviation, unless indicated otherwise. A type I error of p < 0.05 was considered statistically significant.
toward a higher rate in the postintervention cohort (7.6% preintervention vs 12.4% postintervention, \( p = 0.07 \)).

**Discussion**

Judicious postoperative opioid prescribing is essential to minimize opioid misuse and limit the number of pills available for diversion. The extent of the opioid epidemic demands that we act now, and until investigations on appropriate postoperative prescription quantities are completed,\(^\text{21}\) the consensus method may serve as a substitute to form institutional guidelines.\(^\text{15,30}\) To our knowledge, this is the first investigation of an institutional intervention on opioid prescription practices after lumbar spine surgery. Our study revealed that qualitative prescribing guidelines combined with an educational program were effective in reducing the amount and variance of postdischarge opioid prescriptions after lumbar spine surgery. In the 8 months after dissemination of the guidelines, the types of opioid medications prescribed remained relatively the same, whereas providers wrote scripts for fewer pills. This change in prescribing practices may have saved the dispensing of over 26,000 narcotic pills.

Our institution saw a smaller decrease in the amount of opioids given after discharge for spinal fusion surgery. This was likely related to the prevalence of adult deformity seen at our hospital. Our spine service performs a large number of adult deformity corrections—of all the fusion surgeries in the study period, at least 32% were fusions or revision fusions at three or more levels. Given the extent of these procedures, the variability in hospital length of stay, and the inpatient use of opioids, there was likely less of a push to apply a standardized postoperative opioid prescription guideline to these patients, which may have skewed the data toward the null. The procedural complexity in the correction of adult deformity may make it challenging to create standardized quantitative guidelines for postoperative pain management in these patients.

While the focus of this study was to evaluate whether the guidelines could affect prescriber behavior, it was interesting to note that on the patient side, refill rates remained relatively unchanged after the guidelines (7.6% vs 12.4%, \( p = 0.07 \)). We suspect that this difference in refill rates could be significant if applied to a larger population, a finding that would not be unexpected. The overall benefit of decreasing initial opioid prescriptions across the board is not offset by this minor increase in requests for refills, as this difference in refill rates is clinically very small. This finding suggests that overall pain control was not significantly affected by the change in prescription amounts. However, until high-quality data on actual patient opioid consumption is completed, the “minimum necessary quantity” of opioids that minimizes the refill rate and initial prescription OMEs will continue to be elusive.

Successful interventions have been applied to decrease opioid prescriptions after hand and general surgery.\(^\text{15,30}\) For a private practice group of four hand surgeons, Stanek et al. made opioid prescription size recommendations based on the observed distribution of sample data and the consensus among surgeons in the group.\(^\text{30}\) The postoperative pain relief plan was taught to residents, faculty, and nursing staff, while a summary of the postoperative plan was distributed to prescribers in the form of a card. The order set in the EMR was also changed in accordance with this plan. Chart reviews performed 3 months later demonstrated a significant decrease in prescription size in two of four procedural categories, and adherence to the protocol was consistent at 1 year. In a similar intervention, Hill et al. analyzed the opioid consumption of 642 patients who had undergone five common general surgery procedures at an academic hospital, finding that only 28% of prescribed opioids were used.\(^\text{15}\) Quantitative prescribing guidelines were created based on this information. The group presented these guidelines at grand rounds, general surgery department meetings, in resident forums, and through email. Four months after presentation of the guidelines, significant drops in prescription amounts were identified for all five procedures.
Compared to these interventions, ours was similar in that a consensus method was used in the creation of guidelines. However, our department ultimately decided on a qualitative guideline, which differs from the above interventions. While quantitative guidelines are certainly easier for prescribers to follow, without appropriate information (as Hill and colleagues had[15]), a quantitative guideline has the propensity to follow the same habits and misconceptions that led to the overprescribing of opioids in the first place. Our institution is actively conducting a prospective study on postoperative opioid use as part of a plan to revise our guidelines and include set quantities based on this information. Quantitative guidelines may lead to larger drops in prescription quantities—the decrease in prescription amounts recorded in our study was not as large as those reported by Hill et al.[15] (average 53% drop in prescription quantities) and Stanek et al.[30] (15%–48% decreases, depending on procedure). However, an ideal opioid prescribing guideline would likely have both quantitative and qualitative components. Blind adherence to a quantitative guideline may likely have both quantitative and qualitative components. Blind adherence to a quantitative guideline may lead to leftover pills for some, patients' consumption patterns, but this conclusion cannot be definitively made in light of the study's methodology. The interpretation of a qualitative guideline is dependent on the institution's constituents having a shared mental model of the problem at hand. A comprehensive, mandatory educational program can promote a shared mental model of the problem at hand. A comprehensive, mandatory educational program can promote a shared mental model of the problem at hand. A comprehensive, mandatory educational program can promote a shared mental model of the problem at hand. A comprehensive, mandatory educational program can promote a shared mental model of the problem at hand. A comprehensive, mandatory educational program can promote a shared mental model of the problem at hand. A comprehensive, mandatory educational program can promote a shared mental model of the problem at hand. A comprehensive, mandatory educational program can promote a shared mental model of the problem at hand.

The information we ascertained regarding refill rates in patients' consumption patterns, but this conclusion cannot be definitively made in light of the study's methodology.}

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total</th>
<th>Before Intervention</th>
<th>After Intervention</th>
<th>Decompression</th>
<th>Before Intervention</th>
<th>After Intervention</th>
<th>Fusion</th>
<th>Before Intervention</th>
<th>After Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Codeine*</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.1%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tramadol</td>
<td>9.9%</td>
<td>18.7%</td>
<td>8.3%</td>
<td>18.8%</td>
<td>12.6%</td>
<td>18.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxycodone</td>
<td>68.6%</td>
<td>66.2%</td>
<td>74.3%</td>
<td>69.7%</td>
<td>61.6%</td>
<td>60.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrocodone</td>
<td>7.8%</td>
<td>4.1%</td>
<td>9.4%</td>
<td>3.8%</td>
<td>5.0%</td>
<td>4.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydromorphone</td>
<td>11.6%</td>
<td>10.4%</td>
<td>7.3%</td>
<td>7.4%</td>
<td>19.4%</td>
<td>15.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morphine</td>
<td>0.7%</td>
<td>0.3%</td>
<td>0.4%</td>
<td>0.1%</td>
<td>1.2%</td>
<td>0.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>0.146</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Includes pills combined with acetaminophen.

Compared to these interventions, ours was similar in that a consensus method was used in the creation of guidelines. However, our department ultimately decided on a qualitative guideline, which differs from the above interventions. While quantitative guidelines are certainly easier for prescribers to follow, without appropriate information (as Hill and colleagues had[15]), a quantitative guideline has the propensity to follow the same habits and misconceptions that led to the overprescribing of opioids in the first place.
A second limitation of this study was the length of the postintervention follow-up (8 months). While past investigations on prescriber interventions have used follow-up periods of 3–4 months, longer follow-ups are required to determine if these changes are sustained, as has been demonstrated by a previous study. A third limitation of this study was our inability to capture prescriptions written outside the EMR. While the vast majority of prescriptions given after surgery are written from the hospital, we could not capture prescriptions written by the minority of surgeons’ private offices that use EMRs not linked to the hospital EMR. The guidelines specifically prohibited surgeons from sending postoperative opioid prescriptions before the day of surgery, but it was impossible to know how many surgeons followed this recommendation. A fourth limitation relates to data collection from the EMR. When pulling data from the EMR, only the first Current Procedural Terminology code was listed; thus, it is possible that some fusion procedures were mistakenly classified as decompressions. Furthermore, the percent of large fusion cases (i.e., three or more levels) was possibly underestimated. Regardless, the goal of the study was to examine the effect of an institutional intervention on prescriber behavior; thus, this limitation should not affect the overall conclusions of the study.

Conclusions

Opioid misuse in lumbar spine patients is a challenging problem likely to plague providers well into the future. Further research aimed at identifying and recording opioid use patterns after spine surgery will allow for the creation of better-informed, procedure-specific quantitative prescribing guidelines to supplement existing qualitative guidelines. Until that point, institutions can decrease excessive postoperative opioid prescribing by standardizing prescribing behaviors through education and qualitative recommendations. Comprehensive provider education is essential to create a shared mental model on which the institution can base an intervention. This study demonstrates that qualitative guidelines are effective at reducing the amount and number of opioid pills given after lumbar spine surgery. With this reduction in opioid pills at discharge, requests for refills may expectedly increase, but by a clinically insignificant amount that does not offset the overall reduction in opioid prescriptions. Future research is needed to determine the effect of these changes in prescriber behavior on patient outcomes. Furthermore, as the opioid crisis slows, vigilant tracking of prescribing patterns will be necessary to ensure continued adherence to these trends and to prevent a replaying of history.

References


Unauthenticated | Downloaded 09/16/23 04:19 AM UTC

Disclosures
Dr. Albert has been a consultant for NuVasive, Facet Link, Zimmer Biomet, and DePuy Synthes; receives royalties from JP Medical Publishers, Saunders/Mosby-Elsevier, Zimmer Biomet, DePuy Synthes, and Thieme; has served on the Medical Advisory Board for Gentis and United Health Care; has ownership in United Health Care; has direct stock ownership in Gentis, Vital 5, Bonovo Orthopedics Inc., Biomerix, InVivo Therapeutics, Spinality, Crossstrees Medical, Paradigm Spine LLC, Invuity, ASIP, PMIG, and Pioneer; is an employee of Weill Cornell Medical College; has received support from PCORI, NIH, and ISSG for non-study-related clinical or research effort; and is the president of the Scoliosis Research Society and the past president of the Cervical Spine Research Society.

Author Contributions
Conception and design: Lovecchio, Stepan, Premkumar, Derman. Acquisition of data: Lovecchio, Stepan, Premkumar, Steinhaus, Sava. Analysis and interpretation of data: Lovecchio, Stepan, Premkumar, Sava, Derman. Drafting the article: Lovecchio. Critically revising the article: Lovecchio, Stepan, Premkumar, Derman, Kim, Albert. Reviewed submitted version of manuscript: Lovecchio. Approved the final version of the manuscript on behalf of all authors: Lovecchio. Statistical analysis: Lovecchio, Steinhaus, Sava. Study supervision: Kim, Albert.

Supplemental Information
Previous Presentations
Portions of this work were presented as proceedings at the Lumbarspine Research Society Annual Meeting held in Chicago, IL, on April 4–5, 2018.

Correspondence
Francis Lovecchio: Hospital for Special Surgery, New York, NY. lovechciof@hss.edu.